May 1998 www.nasatech.com Vol. 22 No. 5

NASA TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

Product of the Year Winners

Design Show Highlights

Advanced Materials

Electronics Tech Briefs

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TECH BRIEFS

May 1998 • Vol. 22 No. 5

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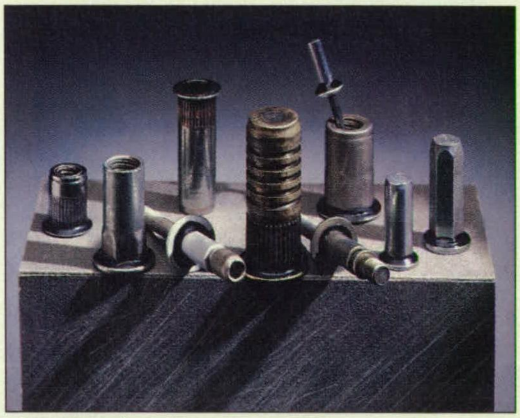
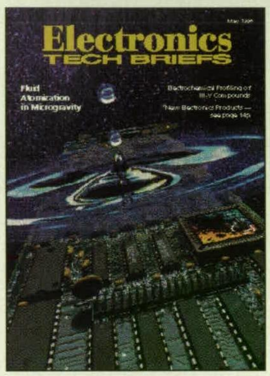


This month's Special Coverage on Advanced Composites, Plastics & Metals features new NASA innovations in ceramics, fiber-reinforced composites, and polyimides. Advances in ceramic materials, polyurethanes, foams, and alloys are some of the new products also featured in this section, which includes ND Industries' (Troy, MI) Plastisol PVC liquid vinyl dispersion material shown here applied to fasteners. Special Coverage begins on page 46.

(Photo courtesy of ND Industries)

Contents *continued*

Special Supplement



Follows page 64 in selected editions only.

On the cover:
The National Design Engineering Show (NDES) in Chicago attracted more than 35,000 design engineers from 23 different industries. One of four events comprising National Manufacturing Week, NDES spotlighted the technologies, solutions, and innovations that will take design engineering into the 21st century and beyond. Products introduced at NDES include quick-disconnect couplings in a variety of materials from Colder Products, St. Paul, MN. Our NDES wrap-up with Product Showcase begins on page 32.

(Photo courtesy of Colder Products)

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Crastin® PBT

By using Crastin® PBT thermoplastic polyester resins instead of metal in this vacuum cleaner fan motor, Electrolux streamlined design, simplified assembly, reduced material costs and improved the motor's efficiency.

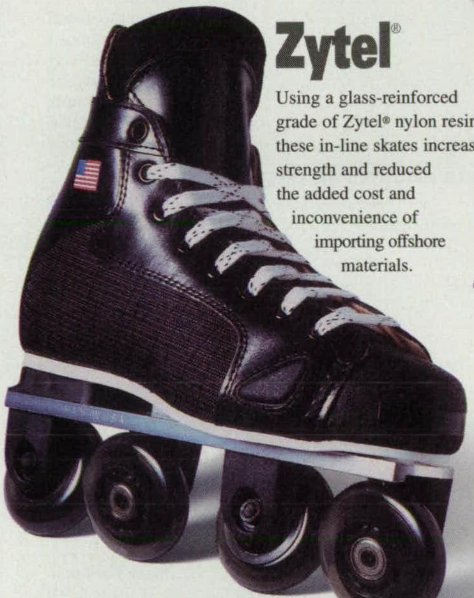
Minlon®

Using Minlon® engineering thermoplastic polymers instead of magnesium in their cylinder head covers eliminated the need for corrosion treatment, and cut BMW's production costs by one-third.

Zytel®

The rugged Thunderbolt rotary hammer features a seven-piece housing and two-piece cord clamp molded from Zytel® nylon resins. Using Zytel® makes the Thunderbolt easier to assemble, and eliminates secondary finishing and painting.

Thunderbolt is a trademark of Milwaukee Electric Company.



Zytel®

Using a glass-reinforced grade of Zytel® nylon resins in these in-line skates increased strength and reduced the added cost and inconvenience of importing offshore materials.

Vespel®

IMPCO Technologies reduced costs in this carburetor by replacing rings and bushings with fully finished Vespel® polyimide parts that eliminated secondary machining. Vespel® parts give longer service life, and more reliable performance—even in temperatures far beyond the engine's normal operating range.

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For More Information Circle No. 504

NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (206) 683-1005 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Bruce Webbon
(650) 604-6646
bwebbon@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3802
duke@louie.dfrf.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@ccmail.jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@gp101.jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Environmental Monitoring; Sensors; Corrosion Protection; Bio-Sciences; Process Modeling; Work Planning/Control; Meteorology.
Gale Allen
(407) 867-6626
gealeallen-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Dr. Joseph S. Heyman
(804) 864-6006
j.s.heyman@larc.nasa.gov

Lewis Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(205) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(601) 688-1929
ksharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

Dr. William Gasko
Center for Technology Commercialization
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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

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bhansen@gm.olmsa.hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Dr. Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1250

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

Joe Boeddeker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Dan Morrison
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622. For software developed with NASA funding, contact the **Computer Software Management and Information Center (COSMIC)** at phone: (706) 542-3265; Fax: (706) 542-4807; E-mail: http://www.cosmic.uga.edu or service@cosmic.uga.edu.

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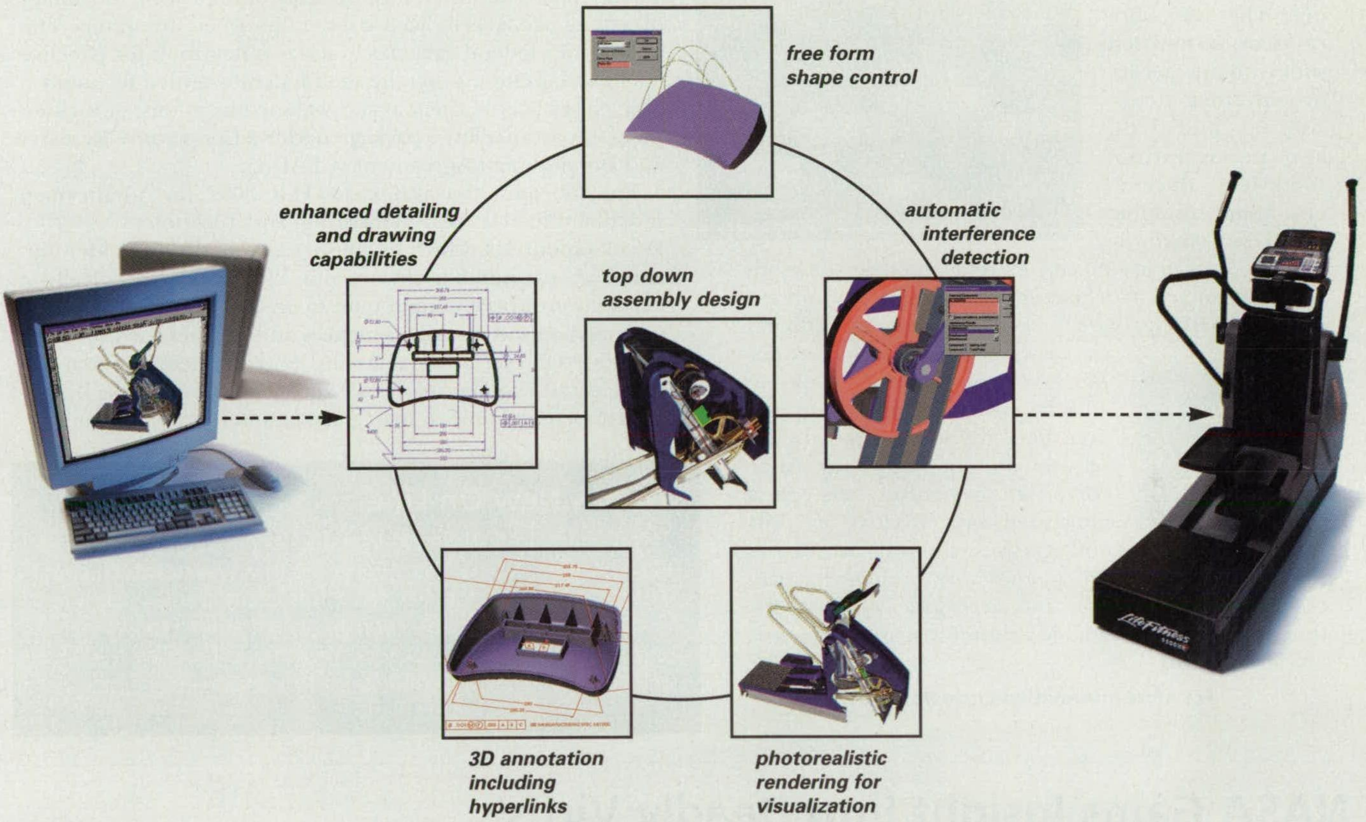

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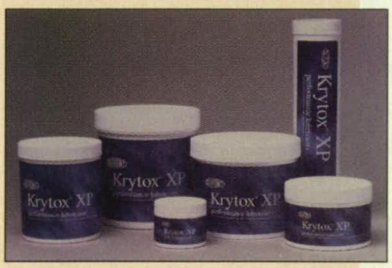

Product of the Month

For More Information Circle No. 754

New Legislation for Women & Tech Transfer

The Science Committee's Technology Subcommittee recently passed H.R. 2544, the Technology Transfer Commercialization Act, with the goal of improving the ability of federal agencies to license federally-owned inventions. The bill permits federal agencies to use two new tools for effective commercialization of on-the-shelf federally-owned technologies: either license them as stand-alone inventions; or include them as part of a large package under a Cooperative Research and Development Agreement (CRADA).

The Subcommittee also passed H.R. 3007, the Advancement of Women in Science, Engineering, and Technology Development Act, which establishes a commission to identify and study the number of women in these fields, specifically in occupations where women tend to be underrepresented. The Commission will describe practices and policies used by employers in recruiting, retaining, and advancing women in science and engineering fields, and determine if these practices are comparable to their male counterparts.

What's New On-Line

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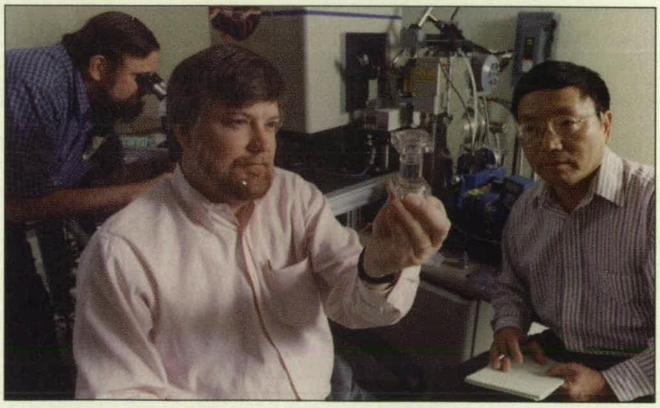
NASA Gains Insight Into Deadly Virus

An important step has been taken by NASA and industry biotechnology researchers toward developing a treatment for a potentially deadly virus that causes pneumonia and severe upper respiratory infection in infants and young children. Called Respiratory Syncytial Virus, the infection attacks the respiratory airways and lungs, and is considered to be the most serious infectious disease in infants in the US, according to physicians. The illness frequently begins with a fever of up to 101°F, and is accompanied by a runny nose, cough, and possibly wheezing or difficulty breathing. Nearly four million children from ages one to five are infected annually in the US, according to the National Academy of Sciences' Institute of Medicine in Washington, DC. About 100,000 of those children require hospitalization, and 4,000 die from the infection.



Dr. Dan Carter (center) examines a chamber of protein solutions prepared for a shuttle flight. Carter's team — Dr. Joseph Ho (right) and Dr. John Ruble — is working with NASA to understand the potentially fatal respiratory infection.

Dr. Daniel Carter, president of New Century Pharmaceuticals in Huntsville, AL, explained that through NASA funding of research in space and on the ground, and by the application of space technology, "we have determined the three-dimensional atomic structure of a potentially very important therapeutic antibody to this virus."

Knowledge of the molecular structure of the antibody will allow scientists to understand interactions between the antibody and the virus, facilitating treatment.

The research is sponsored by the NASA Microgravity Research Program's Biotechnology Office at NASA's Marshall Space Flight Center.

For more information, contact Bob Lessels of NASA Marshall at 205-544-6539, or visit Marshall's web site at: http://www.msfc.nasa.gov

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

Adam Tarpine of DuPont (Reader Forum, February 1998, p. 18) should see some success in applying friction stir welding to polymers, as our company has made a number of test welds in polymers since inventing this process in 1991.

TWI supports NASA's activities in bringing this exciting new joining process to industry's attention. We have successfully applied friction stir welding to many different materials, including all the aluminum alloys, lead, zinc, magnesium, copper, and titanium.

Any organizations interested in using this process should note that TWI has patents covering the process and would be delighted to discuss license terms. Please contact me in this first instance.

Iain J. Smith
Commercial Manager
TWI
Abington, Cambridge, England
ijsmith@twi.co.uk
http://www.twi.co.uk/

The latest aviation headsets use active noise reduction to eliminate low-frequency cockpit noises. I am interested in applying the technology in a manufacturing environment. Can anyone supply me with information such as theories, circuit diagrams, etc., so that I may construct a prototype? Thank you.

Kevin C. Winters, E.I.T.
Saxonburg Ceramics
Monroe, NC
kewinter@juno.com

I am interested in talking to bioengineering companies involved in sanitation, such as bacteria-free applications. Any assistance would be appreciated. Thank you.

Alvin Singer
Singer Associates
San Diego, CA
(610) 487-7748

(From our Online Reader Forum:)

I am searching for a very fast-curing, two-component epoxy that will adhere to plastic and metal. Cure time must be within the 15- to 30-second time range. Any assistance is appreciated.

John H. Chipley

Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864.
Please include your name, company (if applicable), address, and phone number or e-mail address.

How far do you want to go?

Transportation & Public Safety

This month, in our year-long celebration of NASA's 40th Anniversary, we take a look at successful spinoff products and new applications of NASA technologies in the area of Transportation and Public Safety.

1970s

Breathing Easier

In 1971, the nation's fire chiefs were frustrated with the traditional firefighter's breathing apparatus — a cumbersome, mobility-restricting system that was so heavy that it often induced extreme fatigue. In fact, many firefighters chose not to wear the apparatus, risking the possibility of being overcome by smoke rather than suffering from heat and exhaustion. Smoke inhalation injuries, as a result, were rising.

The NASA-developed breathing system was designed with a reduced profile to improve mobility when firefighters are required to squeeze through narrow areas.

NASA's Johnson Space Center (JSC), in cooperation with the Fire Technology Division of the National Bureau of Standards, began a multiyear design and development project to apply technology developed for portable life support systems used by Apollo astronauts on the moon to current firefighting needs. The project received input from the National Fire Protection Association, the International Association of Fire Fighters, and the International Association of Fire Chiefs.

JSC contracted Martin Marietta and Structural Composites Industries to build lightweight air cylinders based on rocket motor casing technology. Scott Aviation built the other components. In 1974-75, a series of field tests was performed with the new system by the fire departments of New York, Houston, and Los Angeles.

The resulting breathing system weighed slightly more than 20 pounds, almost one-third less than the previously used system, and had a reduced-profile design to improve mobility. It included a face mask, frame and harness, a warning device, and the air bottle with valves and regulator. The air cylinder offered the same 30-minute operating time as the previous system, but was lighter and slimmer due to the use of aluminum/composite materials and pressurization that was twice what earlier tanks provided. The frame was easier to put on and take off, and the weight was centered on the firefighter's hips, not on the shoulders. The mask offered better visibility and the air-depletion warning device was heard only by the wearer, minimizing confusion in a hectic fire situation.

After completion of the field tests ten years later, the New York City Fire Department (the country's largest) became one of the first to adopt the new technology on an operational basis. Soon, fire departments across the country began using the system, as firefighting equipment manufacturers incorporated the NASA technology into new breathing systems with their own modifications. Today, every major producer of breathing apparatus incorporates the NASA technology in some form.

Winglets Take Off

A winglet — the vertical extension of an aircraft wing — is a lifting surface that operates in the wingtip vortex, a type of whirlpool that occurs at the plane's wingtips. The turbulent flow of air creates drag, so the winglet's job is to take advantage of the vortex by producing forward thrust, much like a boat's sail. The thrust reduces drag and provides a substantial improvement in fuel efficiency.

Developed by NASA's Langley Research Center, the winglet was part of NASA's Aircraft Energy Efficiency program in the 1970s. Basic winglet technology was demonstrated in wind tunnel and flight tests, but the final design would have to rest with the aircraft manufacturer, since the wingtip vortex effect is different with each type of plane. NASA awarded contracts to aircraft manufacturers to study what the winglet could do for current — and future — commercial aircraft.

Shown in tests on a NASA research plane, winglets (the vertical extensions on the wingtips) produce extra thrust, similar to a boat sail.

Tests with Douglas Aircraft in 1978-79 and McDonnell Douglas in 1982 found that winglets offered a measurable improvement in fuel consumption in the DC-10 and the later MD-11. Winglets are now in regular service on many commercial airliners.

Unsinkable Technology

When the fishing boat Credence overturned off the Alaska coast, the six crewmen scrambled to board an inflatable life raft. Although fishing boats often rely on such inflatable craft as their primary survival equipment, the rafts can be dangerous. But the raft remained stable. Known as the Givens Buoy Raft, it incorporated technology developed by NASA for astronaut recovery. An independent test group found that every type of raft except the Givens could be capsized by one person boarding or by several people shifting their weight. The Givens

The hemispheric underside of the Givens Buoy Raft is designed to prevent capsizing in rough water. The design is similar to that of a NASA raft developed for astronaut recovery after ocean landings.

raft combines NASA technology with independent research by Jim Givens, president of Res-Q-Raft, Inc., of Lake Worth, FL, and Seattle, WA.

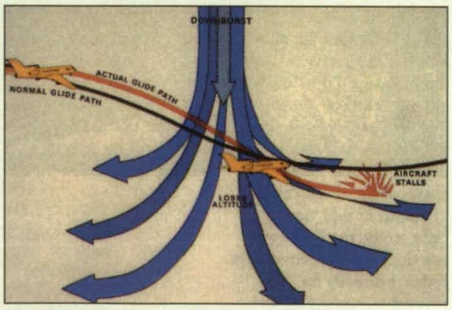
NASA used inflatable rafts to retrieve astronauts from ocean-landed spacecraft, but flat-bottom rafts tended to capsize in the downdraft from recovery helicopters. Johnson Space Center developed a raft-stabilization method for which NASA secured a patent. Givens, who had devised a similar system, patented his own invention and secured an exclusive patent license to use the NASA technology.

The Givens Buoy Raft is gaining wide acceptance among operators of fishing boats and other seagoing vessels. The basic model accommodates up to six persons. A large, hemisphere-shaped underwater ballast chamber provides exceptional stability.

1980s

"Intelligent" Windshear Prediction

Windshear, microbursts, and extreme air turbulence have caused aviation accidents resulting in the deaths of nearly 500 people. Caused by sudden, intense changes in wind speed or direction, these conditions are difficult to detect, making them dangerous to aircraft.



The downburst — a form of windshear — is illustrated.

The downburst is one of several forms of windshear in which a pilot first encounters unexpected lift, to which he or she reacts by dropping the plane's nose. But, a moment later, the full impact of the downburst strikes, and the downward push of the plane is amplified since the pilot already is descending. The pilot has to react quickly to restore the plane to its proper glide path before it stalls.

Federal Aviation Consulting Services (FACS) of Fresh Meadow, NY, has developed a windshear detection/prediction system using artificial intelligence techniques. FACS began developing a computer program in 1985 that would automate the airline dispatch process and include windshear information. The Airline Dispatcher program is intended as a backup system, not as a replacement for human dispatchers. The program would use the same data that a human would request in order to make a decision, and would draw a conclusion based on human rules of logic.

In creating the program, FACS initially used an artificial intelligence program called AESOP that was developed by NASA's Langley Research Center. As the design evolved, the AESOP shell was replaced with a new artificial intelligence program, also developed at NASA, called CLIPS.

FACS, in agreement with Genesis Imaging Technologies, Valley Forge, PA, created a prototype flight dispatcher based on FACS software and a hardware package that incorporates a workstation and an optical disc storage device. The system provides pictorial displays of navigational maps overlaid with flight planning options.

A Weighty Innovation

Overloaded trucks can damage highways and bring costly fines, whereas underloading a vehicle means reduced revenue and profit. LODEC of Lynnwood, WA, has developed electronic weighing devices using aerospace payload-management technology. Using highly accurate electronic scales, truckers can consistently load vehicles to the legal limit, maximizing payload without risking a fine.

The load cell technology, an aerospace spinoff, is used by LODEC to manufacture electronic axle scales for weighing trucks and trailers to insure that they are within legal limits.

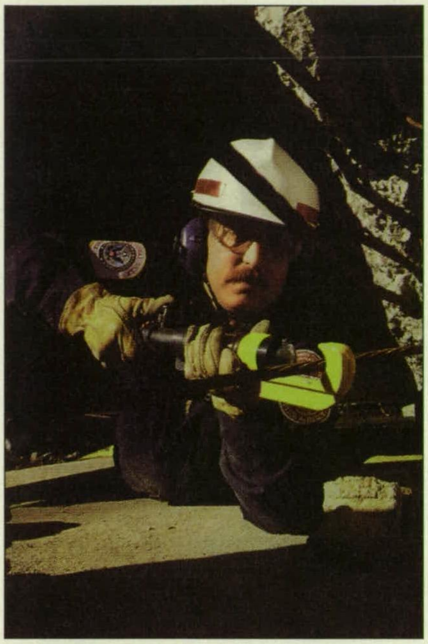
The electronic scales originated with the space program of the 1960s, when ELDEC Corporation acquired advanced electronic technology as a subcontractor on Apollo and Saturn launch vehicles. From this experience evolved an electronic weight-and-balance system for the Lockheed C-5A military transport. LODEC, then the Industrial Division of ELDEC, began adapting the weight-and-balance technology to commercial applications. Their first product was an on-board scale for logging trucks. Loggers had previously relied on "eyeballing" to estimate truck weight. The built-in scale enabled them to carry the maximum legal load without incurring fines. LODEC incorporates similar technology in electronic axle scales for weighing trucks and trailers; a portable version can be used by truckers in remote locations or by weight-enforcement officers on the highway.

1990s

A Life-Saving Spinoff

When the Murrah Federal Building in Oklahoma City was leveled by a bomb, firefighters and other rescue workers had to maneuver under and through concrete rubble to rescue survivors. Their work was assisted by a special instrument — a cutting tool — called Lifeshear, which originally was designed to sever automotive brake and clutch pedals, roof posts, and pillars to remove an automobile's roof and rescue accident victims.

Lifeshear was developed through an Advanced Research



A firefighter clears an egress route by cutting through reinforcement cable and bars in a collapsed structure.

Project Agency-funded, multiple-agency-sponsored Technology Reinvestment Project (TRP) award managed by NASA, in conjunction with the manufacturer — Hi-Shear Technology Corp. of Torrance, CA — and the City of Torrance. NASA had teamed with the City of Torrance Fire Department to develop an earlier-model extraction tool into a new one. The new tool drew the attention of the Federal Emergency Management Agency in Oklahoma City. After rescue workers there used it to penetrate building materials and rescue trapped victims, FEMA ordered 36 cutters and 6,400 power units, and trained rescue personnel in its use.

The power unit, based on NASA-developed pyrotechnics, is what raises the new cutter above its predecessor. Called initiators, the power units look like a shell, or cartridge, and are loaded into the cutter like a shell loads into a gun. The power unit generates hot gases that drive the cutter blade through its target. Using only a nine-gram power unit, Lifeshear is lightweight and compact — measuring 22 to 26 inches long. It takes only 30 seconds to set up, and is available in two sizes: the LS200, a 1.5" cutter, and the LS100, a 4" cutter.

777: The Plane Truth

NASA's Langley Research Center played an important role in the development of the Boeing 777, designed for medium- to long-range passenger flights. The largest twin-engine jet ever made, it began carrying passengers in May 1995, and soon captured three-quarters of the world market for aircraft in its class.

Design and development of the Boeing 777 incorporated a variety of NASA innovations, including lightweight composite materials and the glass cockpit.

Langley-developed analytical techniques and facilities were used by Boeing for the 777. These include fundamental mathematical procedures for computer-generated airflow images, which enabled advanced computer-based aerodynamic analysis. Wind-tunnel testing was performed for flutter and vibration characteristics of the wing structure in Langley's Transonic Dynamics Tunnel. Langley also provided knowledge of how to reduce engine noise and other noise for passengers and terminal area residents.

Langley's Aircraft Landing Dynamics Facility was the site for strength and durability testing of tires, and various Langley advances were used for the 777's modern glass cockpit system that uses computer technology to integrate and display information on monitors in easy-to-use formats. The digital data system, a reconfigurable computer network that allows the plane's computers to communicate with each other; the fly-by-wire system to control wing and tail surfaces; and increased use of lightweight composite structures, including graphite-epoxy floor beams, flaps, and tail assembly all incorporated Langley technologies.

The 777's aerodynamically efficient wing evolved from years of analysis and wind-tunnel research performed at Boeing, and incorporates wing cross-section concepts developed and first published as part of NASA's aeronautical research program. Other NASA centers that contributed to research and technologies adopted for the 777 include Ames, Dryden, and Lewis.

Under Control

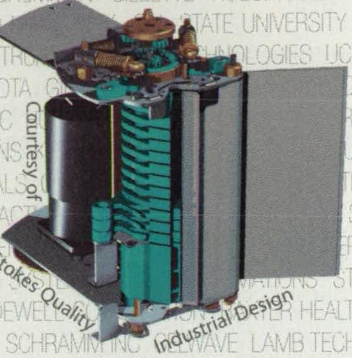
The largest airport built in the past 20 years opened on February 28, 1995 in Denver. While most of the publicity surrounded the kinks in its automated baggage handling system, Denver International Airport boasted another automated system that serves passengers in a more critical way.

The Center-TRACON Automation System (CTAS) is a set of tools designed to help air traffic controllers manage the increasingly complex air traffic flows at large airports. Conceived at NASA's Ames Research Center in the late 1980s, CTAS was brought to the attention of a traffic management coordinator from Denver's Stapleton Airport when he attended a demonstration at NASA Ames. At the time, Stapleton controllers received information on incoming air traffic by phone from Denver's air traffic management center.

In 1993, Stapleton began testing CTAS, and although the equipment operating the system was outdated, the personnel using CTAS were impressed with its capabilities. The input they provided was invaluable to NASA's further development efforts. The system was transferred to the new Denver airport after being modified to allow for the increase in air traffic, number of gates, and number of workers that would be using CTAS. Today, CTAS is Denver International's prime air traffic management tool.

The CTAS system is a software-based set of tools that combines the skill of human controllers with computer-generated advisories, providing human-centered automation. CTAS benefits air traffic controllers by reducing stress and workload, and aids air travelers by reducing delays and increasing safety. In 1991, it was chosen by the Federal Aviation Administration (FAA) as the future automation system for the terminal area.

CTAS is comprised of three major tool sets: the Traffic Management Advisor (TMA), Descent Advisor (DA), and Final Approach Spacing Tool (FAST). TMA increases situational awareness through graphical displays and alerts. It generates statistics and reports on traffic flow, and computes the undelayed estimated time of arrival, the sequences and scheduled times of arrival, and runway threshold for each aircraft. The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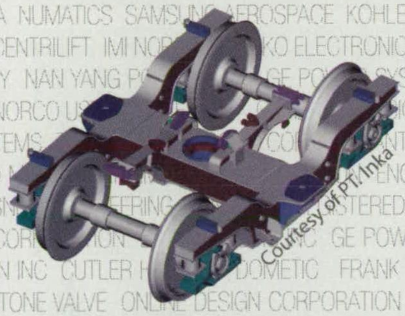
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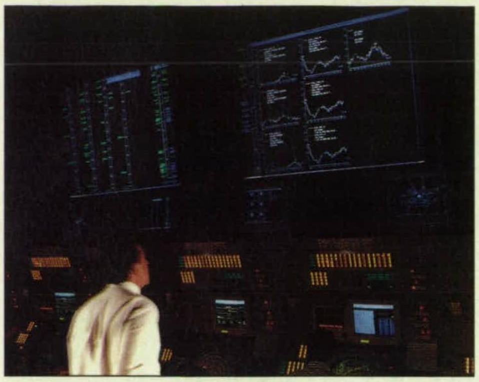

Denver International uses CTAS to help controllers manage air traffic more efficiently. CTAS data is displayed via overhead projectors, allowing controllers to view the information while working at their radar stations.

DA is a four-dimensional flight management system that supports ground-based air traffic control. FAST is a decision support tool for the terminal area controllers that provides landing sequences and runway assignments, as well as speed and heading advisories that help controllers manage arrival traffic and achieve an accurately spaced flow of traffic on final approach.

Since 1976, NASA *Spinoff* has featured many down-to-earth applications of NASA technologies. To learn more about how NASA technologies affect our everyday lives, visit the *Spinoff* web site at: www.sti.nasa.gov/tto/spinoff.html

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Federal Aviation Consulting Services 718-359-4136
Hi-Shear Technology Corp. 310-784-2100
McDonnell Douglas 310-982-8987
Scott Aviation 704-282-8421

(To contact any of the NASA field centers mentioned in this article, see page 14)

Next Month:

NASA Technologies Used in Manufacturing

Looking Ahead ...

• A team of engineers at NASA's Ames Research Center has designed a non-toxic fluid to keep ice from building up on airplanes. It is so environmentally safe, that it has been referred to as "food grade," since ingredients used in its creation have been approved by the Food and Drug Administration for use in food. When used in bulk, the deicer poses significantly less environmental hazard than chemicals currently in use. The fluid also could reduce rust and corrosion on cars, as well as runways, bridges, and ships. The fluid will grab onto an airplane's surface better than current fluids when a plane is at rest. When it takes off, the fluid gets thinner and blows away so the wings are clean. The fluid is being tested as an alternative for salt in ice-removal on highways.

• Represented by Marshall Space Flight Center, NASA and the National Fire Protection Association (NFPA) have signed an agreement to transfer technologies derived from the space program to improve firefighter safety. All ten NASA field centers are participating. The NFPA will provide consultation to support work underway at Marshall with several fire departments. A working group has targeted ten areas for investigation and research, including designing a personnel locator system; developing a vital-signs monitor and transmitter to be worn by emergency services personnel in extreme conditions with high heat, smoke, and chemicals; and developing advanced materials for fire suits. The project will continue through 2002.

• NASA's Lewis Research Center and the Cleveland Regional Transit Authority (RTA) showcased the first hybrid electric transit bus last November. The bus, powered by an electric motor and natural gas-fueled generator, promises increased fuel efficiency and emissions that are one-tenth that of EPA standards. The goal of the $900,000 Ohio Hybrid Bus Project is to develop a vehicle that can operate under severe stop-and-go conditions of city driving while emitting fewer pollutants and costing less to operate. NASA Lewis provided key engineering support in the analysis and design of the power management and control system. The controller allows the bus engine to continue running at near-peak efficiency while stopped in traffic. The resulting excess energy is stored and used later for acceleration. NASA Lewis also designed the vehicle's energy storage system using super capacitors instead of conventional batteries. The electric motor operates almost silently for a more comfortable bus ride.

• NASA is leading an international effort to help prevent accidents by aircraft losing traction on icy runways. Ice or snow was a factor in about 30 airplane accidents between 1983 and 1995, according to the National Transportation Safety Board. A research team in Canada is proving technology concepts to understand contributing factors in those accidents, including inaccurate, incomplete, or confusing runway surface information. The team has developed a runway friction indexing method being tested on snowy and icy runways at the Jack Garland Airport in North Bay, Ontario, Canada. Researchers are comparing friction measurements from ground vehicles and aircraft in different conditions. The index will help pilots with "go/no-go" and "land/go around" decisions based on readings taken on the ground. The program contributes to NASA's effort to reduce the U.S. aircraft accident rate by a factor of five within ten years, and to triple airline system capacity in all weather conditions within ten years.

NASA's instrumented 737 test aircraft lands on a snow-covered runway at North Bay, Ontario. The tests are part of an investigation led by NASA, the FAA, and Transport Canada into winter runway friction.

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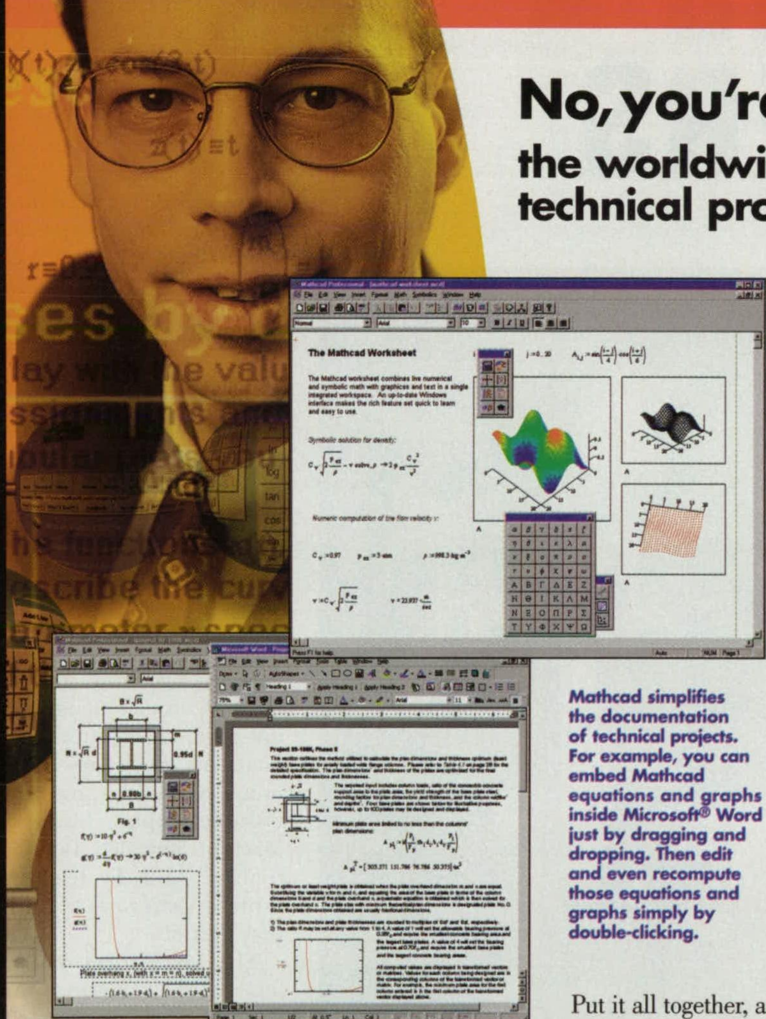

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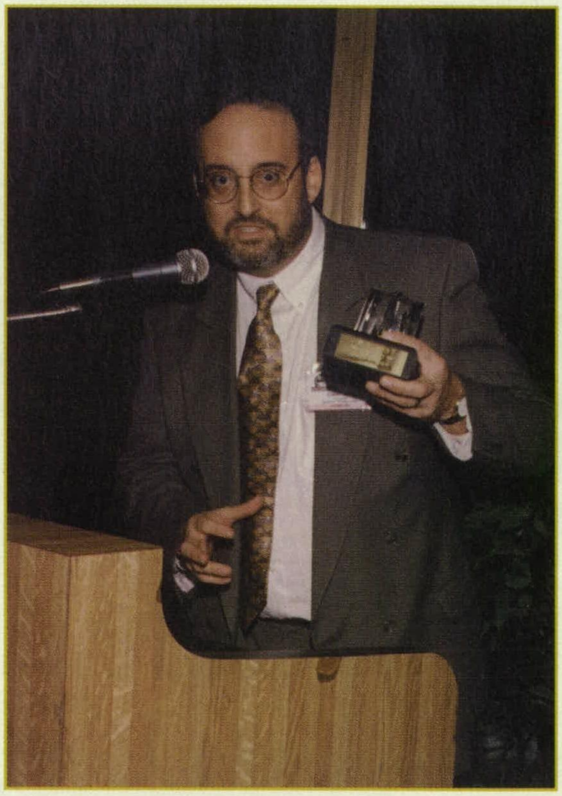
PRODUCT *of the* YEAR AWARD WINNERS

A gala reception in the Signature Room of Chicago's John Hancock Center during National Manufacturing Week was the occasion for the presentation of *NASA Tech Briefs'* 1997 Readers' Choice Awards for Product of the Year. Selected by the readers of *NASA Tech Briefs*, the three top vote-getters were presented, respectively, with the Gold, Silver, and Bronze awards. Nine other Product of the Year Finalists also were presented with awards. All had received Product of the Month honors during 1997.

Each month, *NASA Tech Briefs* designates a Product of the Month, the one product which exhibits exceptional technical merit and practical value. In the December issue, readers are asked to vote for the one product among those highlighted during the year that represents the most significant innovation for the engineering community. The product receiving the most reader votes is named the Gold Award winner for Product of the Year.

The *NASA Tech Briefs* 1997 Product of the Year Gold Award winner was Baystate Technologies of Marlborough, MA, for its CADKEY® 97 mechanical PC-CAD software. The award was presented to Baystate's president and CEO, Robert W. Bean, by *NASA Tech Briefs'* Publisher, Joe Pramberger, and Chief Editor, Linda Bell.



Robert Bean, President and CEO of Baystate Technologies, accepts the Gold Award for *NASA Tech Briefs* 1997 Product of the Year: CADKEY 97 CAD software.

CADKEY 97, for Windows 4.0/95/NT, combines wireframe modeling with ACIS® solid modeling, allowing 2D and 3D data to be imported or exported to other CAD/CAM/CAE applications supporting the ACIS solid modeling kernel. Using OpenGL™ visualization options, the software converts wireframe to solid models; constructs solids such as blocks, cones, and cylinders; and applies extruding, sweep, or revolving geometry into a solid.

The National Design Engineering Show (NDES) marked the introduction of the product's latest version, CADKEY 97 Release 2. This feature-rich edition includes advanced solid modeling without complex constraint tools, solid model creation and freeform editing capabilities, detailing productivity enhancements, and tablet support.

The Silver Award was won by Invention Machine Corp. of Boston, MA, for IM-Phenomenon™ Professional Edition software that creates and analyzes new concepts. Using artificial intelligence, IM-Phenomenon suggests and links effects, enabling users to generate innovations more quickly and completely. Its knowledge base of 1,000 scientific effects, more than 1,000 engineering examples, and 3,400 animation sequences provides descriptions and animated depictions of effects and their advantages. The Windows-based software suggests an effect or combination of them that meets the user's needs, then provides descriptions that include formulae, engineering advantages, limitations, materials necessary, additional references, and real-world examples. Invention Machine unveiled TechOptimizer™ 3.0 Professional Edition software at this year's NDES.

The MathWorks of Natick, MA, garnered the Bronze Award for its MATLAB 5 technical computing software. It provides a single environment for analysis, visualization, modeling, simulation, and large-scale application development and deployment. Features include realistic 3D visualization and presentation graphics, and application development tools such as browser-based documentation and visual editor/debugger. It is available for Windows, Macintosh, and UNIX platforms.

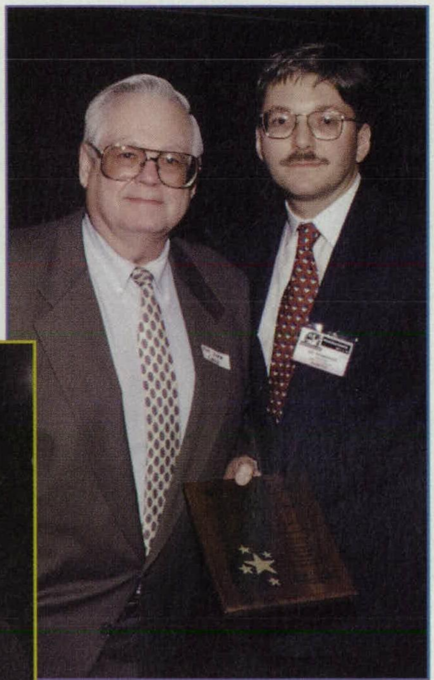
NASA Tech Briefs Publisher Joe Pramberger (right) and Chief Editor Linda Bell present the Silver Award for Product of the Year to Scott Todaro, marketing manager of Invention Machine Corp., for the IM-Phenomenon software.

All readers who submitted ballots by the deadline date were placed in a random drawing from which three winners were chosen. Congratulations to the following *NASA Tech Briefs* readers:

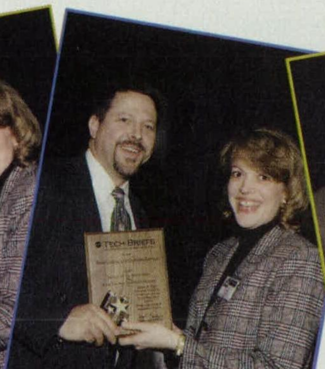
- William De Ojeda of Melrose Park, IL, winner of an FW7000 Series rugged laptop computer from FieldWorks, Eden Prairie, MN;
- David Peterson of La Grange, IL, winner of Solid Edge CAD software from Unigraphics Solutions, Huntsville, AL; and
- Ernest Bayazitov of Folsom, CA, winner of SolidWorks 97Plus mechanical CAD software from SolidWorks, Concord, MA.

The following companies and their products were honored as Product of the Year Finalists:

- Cad.Lab of Santa Clara, CA, for Eureka Gold 97 3D mechanical design software
- Gage Applied Sciences of South Burlington, VT, for the CompuScope 8500/PCI multimegahertz data acquisition system
- Hewlett-Packard of Palo Alto, CA, for the Infinium family of oscilloscopes
- Manufacturing and Consulting Services of Scottsdale, AZ, for Anvil Express CADD/CAM solid modeling software
- National Instruments of Austin, TX, for DAQScope™, DAQMeter™, and DAQArb™ PCI, ISA, and PCMCIA instrumentation computer interfaces
- Polytel Computer Products of Sunnyvale, CA, for DraftPAD, a programmable touchpad for computer keyboards
- Keyence Corp. of America of Woodcliff, NJ, for the CV Series Compact Vision System, a handheld machine vision system
- Racal Recorders of Irvine, CA, for the Racal-Heim DATaRec A60 data recorder
- SoftSource of Bellingham, WA, for Vdraft™ AutoCAD-drawing-based CAD software



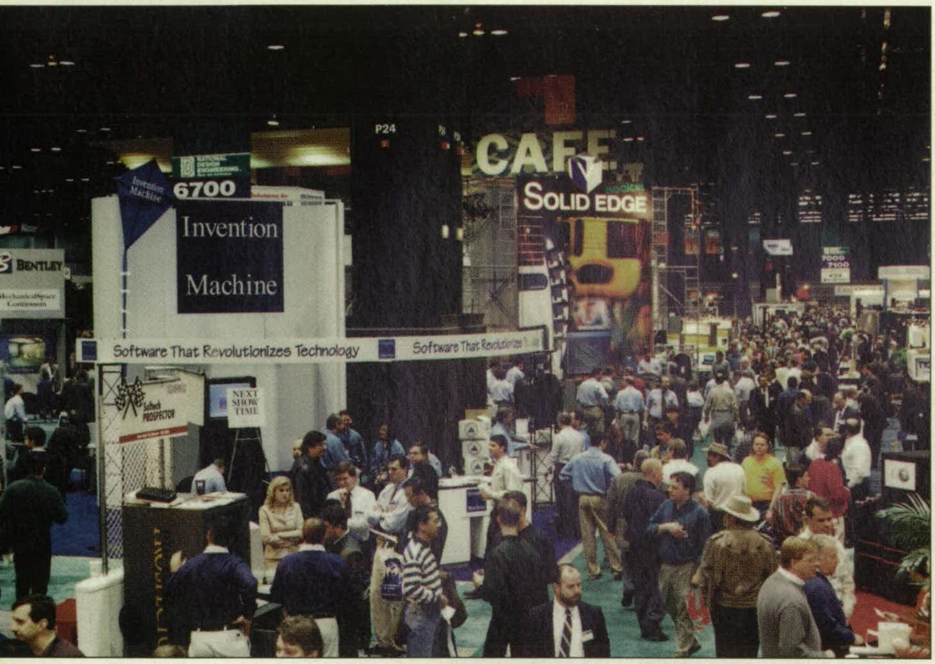
Product of the Year Finalist awards were presented by *NASA Tech Briefs* Publisher, Joe Pramberger, to (at left) Sandy Costello, marketing manager for Cad.Lab; and Ron Zimm (above), for Gage Applied Sciences.



NASA Tech Briefs Chief Editor, Linda Bell, presented Product of theYear Finalist awards to (from left): David Potter of National Instruments; Scott M. Hanratty of Manufacturing and Consulting Services; David Harrington of Polytel Computer Products; and Jay A. Alexander of Hewlett Packard.

National Design Engineering Show

Engineering and Beyond



More than 35,000 design engineers from 23 different industries attended the National Design Engineering Show (NDES) in Chicago in March. One of four events comprising National Manufacturing Week, NDES spotlighted the technologies, solutions, and innovations that will take design engineering into the 21st century.

McCormick Place housed the more than 1,000 NDES exhibitors displaying products, services, and systems in electronics, CAD/CAE/CAM, fastening and joining, mechanical components, power transmission, motion control, and other areas.

Space Exploration Day, one of the week's special events, featured a panel of leading space researchers discussing "Space Technology and Its Application to Industry." The four-member panel was moderated by Dr. Ray Galvert, coordinator of commercial products and services at NASA Headquarters, who is responsible for promoting the commercial development of space and sharing that technology with American industry. Galvert said that it is NASA's hope that businesses " begin to see that a real competitive advantage can be gained by working with NASA to develop tomorrow's products and technologies."

The panel was made up of Dr. Tony Overfelt, project director for solidification design at the Center for Space Commercialization (CSC), Auburn University; Dr. Alex Ignatiev, director of the Space Vacuum Epitaxy Center (SVEC) at the University of Houston; Dr. Al Sacco, director of the Center for Microgravity Materials Processing (CMMP) at Northeastern University; and Dr. Frank Schowengerdt, director of the Center for Commercial Applications of Combustion in Space (CCACS).

Overfelt described how the CSC uses microgravity testing to develop industrial castings. By testing thermal physical properties of metals such as titanium and nickel without container contamination, "true" values can be entered into computer models, allowing engineers to better predict casting defects and reduce scrap losses.

Ignatiev and his industrial partners developed an "ultra vacuum" using a free-flying 12-foot disk called the Wake Shield. When released into space, it creates a vacuum 1,000 times anything found on Earth, allowing for production of purified materials for improving semiconductors, lasers, and flat-display screens.

Under Sacco's direction, the CMMP has studied formation of Zeolites in a microgravity setting to better understand how they form on Earth. These aluminosilicate crystals are highly porous, containing submicroscopic channels and active catalytic sites. Applications include petroleum, chemical, and environmental industries.

Schowengerdt discussed how the CCACS uses microgravity testing of water-mist fire-suppression methods in developing a replacement for the environmentally unsafe Halon systems currently used. Studying water-mist formation in microgravity provides important design information for nozzles and other firefighting components.

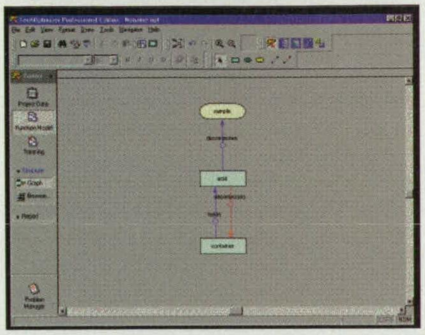
At the NASA pavilion on the exhibit floor, NASA representatives performed science and technology demonstrations, and discussed how research aboard the International Space Station will improve life on Earth. They emphasized how materials-science research in space enhances existing manufacturing processes and products. Exhibits included a 1:8 scale model of the new X-33 launch vehicle, in addition to a walk-through mock-up of the International Space Station science laboratory and crew's living quarters.

NDES New Product Showcase

Following are new products and technologies introduced at the National Design Engineering Show.

Problem-Solving Software

Invention Machine Corp., Boston, MA, introduced TechOptimizer™ 3.0 Professional Edition software that helps engineers and scientists resolve engineering problems at a conceptual level.

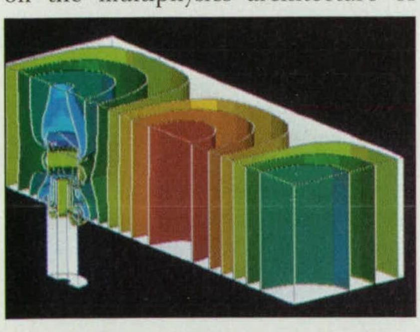


It integrates the functionality of TechOptimizer™ 2.5 Professional Edition with the knowledge base of IM-Phenomenon™ software for automatic creation of new concepts. The new version contains six modules: Product Analysis, to identify functional requirements and generate a problem statement; Process Analysis for analyzing a sequence of operations; Feature Transfer, to send features from one engineering system to another; Effects, which provides more than 4,000 animated engineering and scientific effects and examples; Principles, for applying inventive principles to a problem; and Prediction, to solve technical problems by involving interactions between objects.

For More Information Circle No. 772

Drop-Test Analysis

ANSYS, Canonsburg, PA, announced a drop-test module add-on to the ANSYS/LS-DYNA™ impact simulation software. The module features a customized graphical user interface that provides real-world simulation of product impact testing. The add-on is built on the multiphysics architecture of ANSYS® software, enabling step-by-step management of drop-test analysis. Preexisting models also can be prepared for impact simulation. Other add-on modules include fatigue and fracture mechanics, and full-wave electromagnetic simulation.



For More Information Circle No. 757

New Fitting Family

New additions to the Prestolok® family of fittings have been introduced by Parker Hannifin's Fluid Connectors Group, Cleveland, OH. The Prestolok II extended male elbow swivels for pneumatic assembly on cramped manifolds, and is available in lengths from 1-3/16" through 2-1/4". Prestolok fittings for metric tubing are nickel-plated fittings available with NPT male threads. They are available in straight and elbow versions for size 6, 10, and 12 metric tubing. Prestolok II fittings with stainless steel internal components are available with stainless steel NPTF pipe threads; Prestolok II female NPTF elbows and tees feature composite bodies; and Prestolok II fittings with BS21 parallel pipe threads are designed to connect to fractional inch tubing.

For More Information Circle No. 767

3D Design in Windows

SolidWorks Corp., Concord, MA, introduced SolidWorks 98, the fifth major release of the Windows-native 3D mechanical design software. The new version includes more than 150 enhancements, including new part and assembly modeling features, and more powerful drawing capabilities. Other enhancements include multi-threaded retrieval capabilities; the ability to defer the rebuilding of parts, assemblies, and drawings on request; sketching and sheet metal enhancements; the ability to import and export assemblies and reference surfaces via IGES; IGES/DXF import of 3D curves; and the ability to save documents as TIFF images.

For More Information Circle No. 759

New Fastener Family

New PEM® self-clinching fasteners have been released by Penn Engineering & Manufacturing Corp., Danboro, PA. The new fasteners include the Type FHL™ flush-head studs for closer-to-edge and minimal space applications; the Type PF11™ panel fasteners; Type FH14™ flush-head studs; Type TSO™ standoffs for ultra-thin sheets; Type TPS™ pilot pins; and R'ANGLE™ right-angle clinch fasteners, which are designed to provide a strong right-angle attachment point in aluminum sheets as thin as 0.040". All fasteners incorporate the self-clinching principle for permanent, streamlined installation using less hardware.

For More Information Circle No. 771

Advanced Graphics Workstations

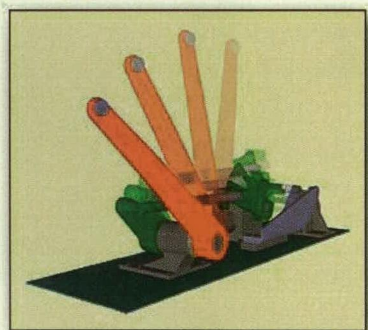
Intergraph Computer Systems, Huntsville, AL, offers the TDZ 2000 ViZual Workstations, which incorporate the new RealiZm II VX113 graphics subsystem. The newly equipped Windows NT workstations allow MCAD designers to work at high resolutions with true color depth, view complex assemblies from multiple perspectives, and iterate designs in assembly context with rapid re-draws. The workstations are scaleable

to meet demands of various levels of 2D and 3D graphics required for MCAD tasks, such as sketching, drawing, solid modeling, assembly design, or engineering analysis.

For More Information Circle No. 770

Integrated Software

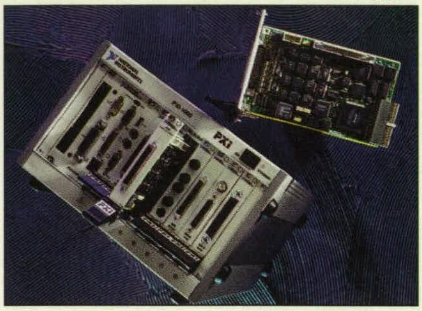
Working Model, San Mateo, CA, has teamed with Structural Research and Analysis Corp. (SRAC) to develop the Automated Load Transfer™ (ALT) capability in Working Model 3D simulation software. The feature streamlines concurrent analysis conducted with SRAC's COSMOS/Works and SolidWorks CAD software. The ALT technology will enable COSMOS/Works users to determine load cases for individual parts within static or moving SolidWorks assemblies. The integration of the three CAD, function simulation, and FEA software packages will enable engineers to produce refined designs more quickly and accurately.



For More Information Circle No. 761

New Motor Controllers

The PXI-7314 open loop and the PXI-7324 closed loop stepper motor controllers were introduced by National Instruments, Austin, TX, to provide motion control for stepper motor applications for CompactPCI and PXI systems. The systems are compatible with the company's LabVIEW™, BridgeVIEW™, LabWindows™/CVI, and C/C++. The modules can control up to four stepper motors with programmable pulse and direction or clockwise/counter-clockwise output signals. They feature an onboard Motorola real-time CPU that off-loads the host PC, manages motion control tasks, integrates digital I/O, and runs command sequences in motion applications. The controllers include free pcRunner motion software for Windows 95/NT.



For More Information Circle No. 775

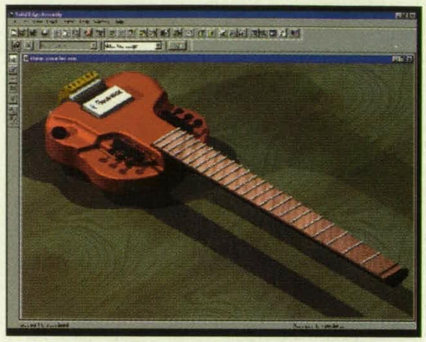
Process Control System

Rockwell Automation, Mayfield Heights, OH, introduced the Allen-Bradley ProcessLogix™ process control system that combines server-based distributed control system technology with ControlLogix™ control architecture for integrated sequential, motion, process, and drive system applications. The system blends software, hardware, and a global database into a single system that incorporates ControlNet™, an open network for data transfer. A development environment includes standard displays such as alarming, trending history, and reporting for quick set-up. A custom display builder features a library of common plant equipment such as pumps, valves, and tanks.

For More Information Circle No. 776

2D/3D Design

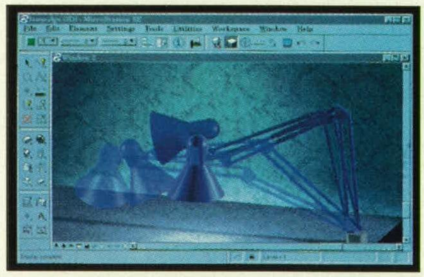
Solid Edge Version 5 CAD software was introduced by Unigraphics Solutions, Maryland Heights, MO. The new release is powered by the company's Parasolid modeling kernel, and includes more than 100 new design capabilities. The software offers fully integrated assembly modeling, part modeling, sheet metal, and drafting environments in a 2D-to-3D design system. Other features include enhanced DXF and IGES translation; interoperability with Unigraphics CAD software; large-assembly management tools; and additional functionality for creating and manipulating complex features. Solid Edge Version 5 is written for use on Windows 95 and NT platforms.



For More Information Circle No. 763

Complex Parts Placement

Dynamic assembly modeling for mechanical design automation was announced by Bentley Systems, Exton, PA. The new capability was the result of a joint development effort which incorporated the ADAMS® interactive 3D constraint solver from Mechanical Dynamics, Ann Arbor, MI into Bentley's MicroStation Modeler®. Dynamic assembly modeling enables the placement of parts into constrained assemblies, eliminating the trial-and-error process of placing parts within a complex design. The ADAMS solver calculates degrees of freedom in real time, and the MicroStation Modeler dynamically guides users to optimal placement. It can be used in designing all types of assemblies, including automotive, aerospace, and consumer products.



For More Information Circle No. 768

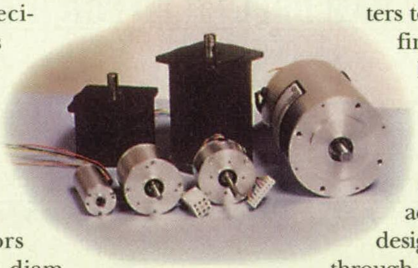
Drag-and-Drop CAD

Visionary Design Systems, Santa Clara, CA, offers IronCAD™ 3D modeling software based on a proprietary Design Flow™ Architecture that features drag-and-drop solid modeling and natural 3D interaction. The Windows program captures design intent from any model created by any CAD system, allowing modifica-

tions to be made by any collaborator at any time in the design process. Other features include real-time texture, bump, and decal mapping; advanced rendering, animation, and visualization capabilities; and 3D CAD import and export filters for a variety of standards.

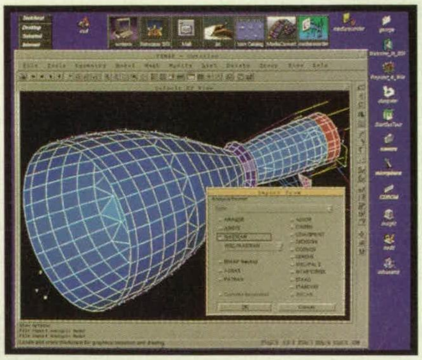
For More Information Circle No. 760

Brushless Motor Line



The Silencer™ series of Clifton Precision® brushless DC motors has been introduced by Litton Poly-Scientific, Blacksburg, VA. The motors are available in diameters from 1.2" to 4.0" and lengths from 1.3" to 5.5". Continuous torques range from 2.4 to 519 oz-in with speeds to 20,000 RPM. They feature high-energy bonded rare-earth magnets and an aluminum housing for rugged environments, and are designed for applications where low noise is a consideration, such as medical equipment and robotics. Standard options include electronic drivers, encoders, and gearheads, as well as Hall effect, resolver, and sensorless feedback.

For More Information Circle No. 712



UNIX Analysis Software

Enterprise Software Products, Exton, PA, has released a version of its FEMAP® engineering analysis modeling and visualization software for UNIX workstations from Silicon Graphics, Hewlett-Packard, Sun, and IBM. FEMAP 5.0 provides UNIX users with the software's full functionality that was available previously on a PC. Features include a Motif-compliant user interface with the same menu options as the Windows version, as well as optimized OpenGL graphics speed and robust access to CAD geometry.

For More Information Circle No. 764

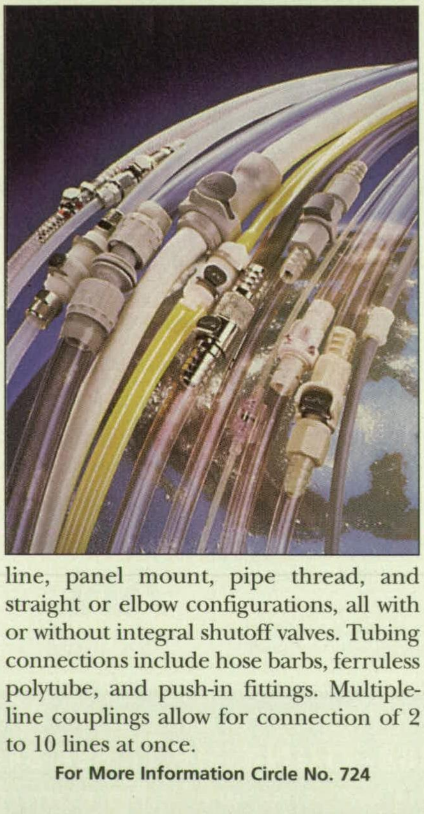
Ring Selection Software

Smalley Steel Ring, Wheeling, IL, has introduced free retaining ring and wave spring software for design engineers. Thousands of catalog items can be searched using actual assembly parameters to reduce the time needed to find standard parts. Calculations then can be performed on a standard part to check performance in the design. Custom parts can be designed using interactive features such as a spring design wizard that guides users through the spring design process.

For More Information Circle No. 721

Quick-Release Couplings

Colder Products, St. Paul, MN, has introduced a line of couplings that feature a thumb latch for quick disconnects, and an audible click to verify a secure, leak-free connection. CPC couplings are available in a variety of materials, including ABS, polycarbonate, polypropylene, polysulfone, and chrome-plated brass. Standard mounting options include in-



line, panel mount, pipe thread, and straight or elbow configurations, all with or without integral shutoff valves. Tubing connections include hose barbs, ferruless polytube, and push-in fittings. Multiple-line couplings allow for connection of 2 to 10 lines at once.

For More Information Circle No. 724

Components Resist Shock

Sorbothane, Kent, OH, offers vibration- and shock-isolation components, including custom-molded products for applications requiring shock absorption, vibration isolation, and acoustical damping. Also available is a line of standard shock mounts and vibration isolators that can be used in automo-

tive parts, computer hardware, circuit boards, industrial machinery, and laboratory equipment. The Sorbothane material offers high damping properties over a broad temperature and frequency range.

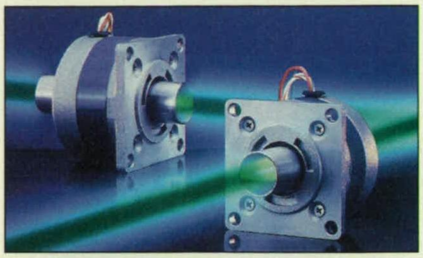
For More Information Circle No. 715

Conductive Material

Tecknit, Cranford, NJ, introduced NC-Consil nickel-coated graphite-filled silicone material that consists of nickel-coated graphite particles in a silicone elastomer. It provides electrical conductivity, broadband shielding, and environmental sealing. The material is available in sheet/rule die-cut parts, extruded profiles, and molded shapes. A compatible nickel graphite,

conductive, one-component, RTV silicone adhesive-sealant also is available with shielding effectiveness >100 db@ 1 GHz.

For More Information Circle No. 729



Stepping Motors

Eastern Air Devices, Dover, NH, offers a bidirectional, size 23, single-stack DC hollow-shaft stepping motor that measures 2.25" x 2". The motor is based on a 1.8-degree step with position accuracy of ±3 percent non-cumulative. Peak torque is 50 oz-in. A variety of windings is available for all types of unipolar and bipolar drives. The motor features permanently lubricated ball bearings, and is available in variety of frame sizes, cable, connectors, encoders, special brakes, and shaft modifications in various lengths, widths, and special-tooled end combinations. The stepper is designed to allow electrical and optical cables to pass through motors.

For More Information Circle No. 730

Planetary Gearheads

Type MNA low-backlash planetary gearheads from Mijno Precision Gearing, Park Ridge, IL, mount onto NEMA MG-7 dimensioned size 23, 24 and 42 stepper or servo motors. Features include needle bearings on the double-supported, hardened satellite gears; and ball bearings on the output shaft. The gearheads are available in standard or custom configurations. Standard backlash is 20 arc-mins maximum with 10 arc-mins in some sizes. A variety of gear ratios is available from 3 to 100/1. Rated life is 10,000 hours, and all-position mounting is enabled with grease lubrication.

For More Information Circle No. 725

CAD Simulation

MSC/InCheck for Solid Edge Version 5.0 is available from MacNeal-Schwendler Corp., Los Angeles, CA. The Windows 95/NT workstation and PC program provides stress, vibration, buckling, heat transfer, and shape optimization simulation that is seamlessly integrated with Solid Edge design software from Unigraphics Solutions. Solid Edge users can create, analyze, and review results of MSC/InCheck simulation models directly within the Solid Edge interface, using Parasolid solid geometry. The program generates web-enabled results reports, allowing Solid Edge users to communicate design performance using the Internet.

For More Information Circle No. 758

Motors and Drives

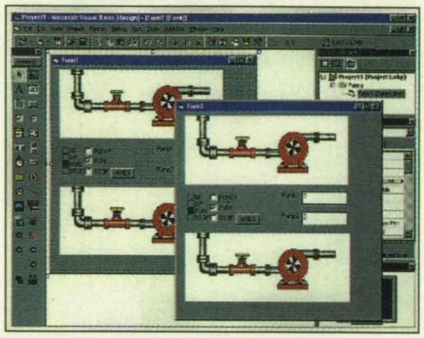
Baldor Electric, Fort Smith, AR, offers a variety of electric motors and drives, including energy-efficient AC and DC motors through 800 HP; adjustable-speed drives, including

inverter and vector controls; servo motors, controls, and accessories; gear motors and speed reducers; solid-state soft starters and dynamic brakes; and pre-engineered control panels. Also available are spindle drive motors; square flange pump motors and encoderless vector controls; and hollow-shaft gear reducers.

For More Information Circle No. 732

Logic Control System

SIMATIC WinAC PC-based soft logic control system was introduced by Siemens Energy & Automation, Alpharetta, GA. The system allows users to perform standard PC applications, as well as process visualization or open-loop control on a single, open hardware platform. The Windows NT-based system provides integration of software components for control, engineering, data processing, communication, and visualization tasks. The package with accelerator board (the SlotPLC) can be used to attain deterministic behavior and data security of a PLC. The SoftPLC is the standard



format logic control software that manages control tasks such as loading, starting, and basic diagnostics.

For More Information Circle No. 777

Linear Bearing

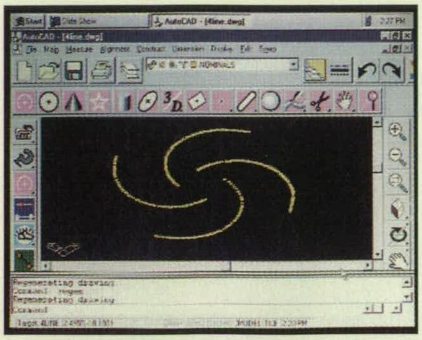
The zero-clearance Nyliner™ polymer bearing from Thomson Industries, Port Washington, NY, is a self-lubricating, constant-preload linear/rotary bearing for moderate load applications such as instruments, computer hardware, and medical equipment. Zero clearance is maintained by the pressure exerted by the tips of preloaded curved pads upon the shaft. It can be produced in differ-

ent composites to meet thermal, chemical, and load requirements. It can be used in temperatures to 250°F, and is available in sizes ranging from 1/4" to 1-1/2" nominal ID.

For More Information Circle No. 733

3D Inspection Measurement

AnthroCAM® 2.0 CAD-based 3D inspection measurement and reverse engineering software from FARO Technologies, Lake Mary, FL, works with the company's FaroArm® six- and seven-degrees-of-freedom portable coordinate measurement arms. The software incorporates Autodesk's Mechanical Desktop™ and operates on Windows 95 and NT. The software fea-



tures a large digital readout and an adjustable results box so operators can read measurements from a distance. A 3-2-1 alignment feature enables operators to select an xy, yz, or zx base plane for measurement.

For More Information Circle No. 745

Hydraulic Seal

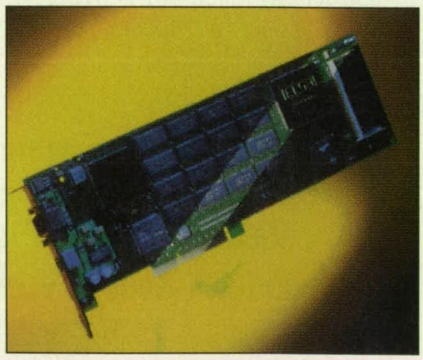
Busak+Shamban, Seals Division, Fort Wayne, IN, offers Turcon® Glyd Ring® T bidirectional dynamic seal for industrial hydraulic systems. The seal features low friction, contamination resistance, and

blow-by prevention. It also offers extrusion resistance and can accommodate larger extrusion gaps. The seal can be incorporated with the Turcon® Stepseal® K and a variety of scrapers to form a sealing solution for new and retrofit applications.

For More Information Circle No. 741

Graphics Accelerator

ELSA, Santa Clara, CA, announced the Gloria™-XXL 3D graphics accelerator for CAD modeling, animation, and visualization applications. Based on the GLINT® GMX 1000 chipset, the unit can accelerate up to 3.3 million polygons per second, with geometry transformation, lighting calculations, texture



coordinate generation, and fog calculation. It is configured with a 16-MB VRAM frame buffer and 24 MB DRAM — expandable to 40 MB — local buffer memory for Z-buffering and texture mapping. It supports high-resolution, true-color display of up to 1920 x 1080 or 1600 x 1280 on 24" monitors.

For More Information Circle No. 779

Commercialization Opportunities

Fiber-Reinforced-Plastic/ Concrete Structural Members

Fiber-reinforced-plastic (FRP) shells encasing concrete strengthen and protect structural members against erosive forces. Use of FRP can be especially advantageous for bridges and similar structures in hurricane-prone coastal areas, earthquake zones, and regions with freeze/thaw cycles.
(See page 48.)

Creep-Resistant Ceramic Composite for High-Temperature Use

A low-density, prototype composite material has been developed for high-temperature service in next-generation aircraft engines. The improved matrix material incorporates alumina, silica, and mullite.
(See page 51.)

Nearly Isotropic Resin-Transfer-Molded Composites

Unlike earlier composites, these can be machined to fine detail. Their fine weave withstands machining with minimal loss of mechanical properties.
(See page 52.)

Joining of SiC-Based Ceramic and Fiber-Reinforced Composite Parts

A process involving reaction forming enables the joining of high-temperature-resistant structural parts made of SiC-based materials. Simpler parts can thus be joined to form more complex parts. The joints have retained strength from ambient to 1,370 °C.
(See page 54.)

Automated Vision System Inspects a Large Surface

A computer-controlled high-resolution video camera on a scanning robot arm and two stroboscopic illuminators automatically inspect large surfaces for damage. The system produces a data base for review and analysis and replaces earlier labor-intensive procedures.
(See page 66.)

Probes for Measuring Pressures in Flowing Gases

Improved pressure probes give nearly instantaneous readings. These probes could be particularly useful as pressure-sensing instruments to characterize airflow about aircraft. The readings can serve as inputs to advanced digital flight-control systems.
(See page 78.)

Electromagnetic Smart Washer for Detecting Bolthole Cracking

Sensors connected to the smart washer detect changes in electromagnetic fields around a bolthole, indicating bolthole cracks. The washer can reliably detect cracks as short as 0.050-in. (1.27-mm).
(See page 80.)

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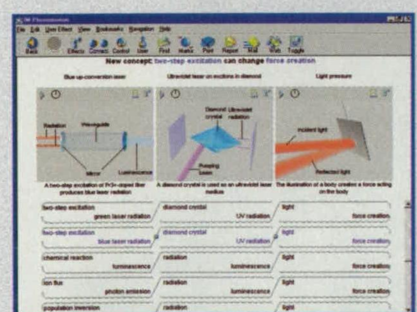

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For More Information Circle No. 524

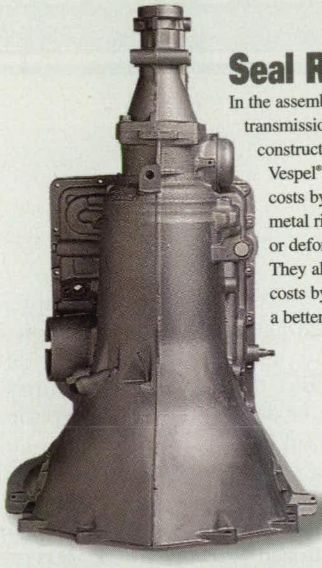
In today's world of engineering, time is money, and IM-Phenomenon saves you both.

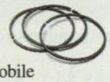
There are a ton of reasons to use Vespel® just about anywhere.

The reasons to use Vespel® polyimide parts and shapes keep piling up. And not just because they stand up to heat, friction, pressure and aggressive environments – with minimal or no lubrication. Manufacturers are finding that Vespel® parts in a wide range of applications can really trim the bottom line. That's because the reliability and long life of Vespel® parts can make them the most cost-effective choice for general applications in the long term.

If your applications require parts that can withstand extreme temperatures (cryogenic to 550 F), Vespel® should be your first choice. Vespel® should also be considered for parts that rub together, if metal parts are too noisy, or if fluid flow needs to be controlled.

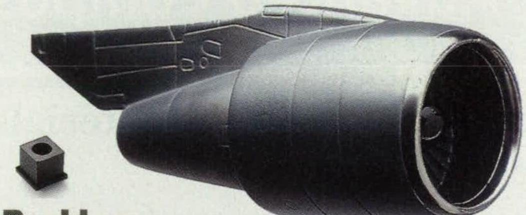
Superior performance and reliability aren't the only ways Vespel® can save you money. Often, you can consolidate two or more existing parts in one Vespel® piece.





Seal Rings.

In the assembly of automobile transmissions, and farm and construction equipment, Vespel® seal rings reduce costs by replacing expensive metal rings, which can fracture or deform during assembly. They also reduce warranty costs by producing a better seal.

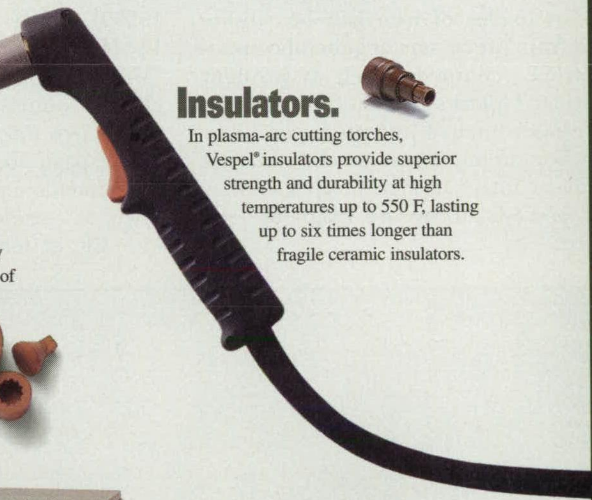


Bushings.

In aircraft engine vanes, Vespel® bushings withstand high-frequency vibration dithering and offer excellent stability and lubricity at extreme temperatures. They also reduce assembly time.

Thrust Devices.

The automotive industry counts on Vespel® thrust devices because they reduce friction, extend component life and can be easily molded. What's more, the variety of Vespel® grades allows manufacturers to specify the properties they need most.



Insulators.

In plasma-arc cutting torches, Vespel® insulators provide superior strength and durability at high temperatures up to 550 F, lasting up to six times longer than fragile ceramic insulators.

Thrust Washers.

In construction equipment transmissions, Vespel® thrust washers reduce costs and manufacturing time by eliminating the need for secondary machining. Vespel® washers also withstand high pressure and exhibit minimal wear with limited or no lubrication.

Compressor Discus Valves.

Supermarkets are cooling foods more efficiently with discus compressors, featuring components made of Vespel®. Vespel® not only reduces energy and noise levels, but it also offers excellent wear resistance. The Vespel® part is expected to operate for 15 years without failure.

Stripper Fingers.

Thanks to its high temperature resistance, Vespel® parts are ideal for copier stripper fingers. The Vespel® fingers resist heat as well as toner buildup, allowing a greater number of copies without part changes.

And Vespel® parts can be direct-formed, which eliminates machining costs.

When you consider how cost-effective Vespel® parts can be in the long term, it's clear that we don't just make better bushings, bearings, washers and seals. We make better sense.

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For More Information Circle No. 529

Iron-Containing Carbon Materials Made From Graphite Fluoride

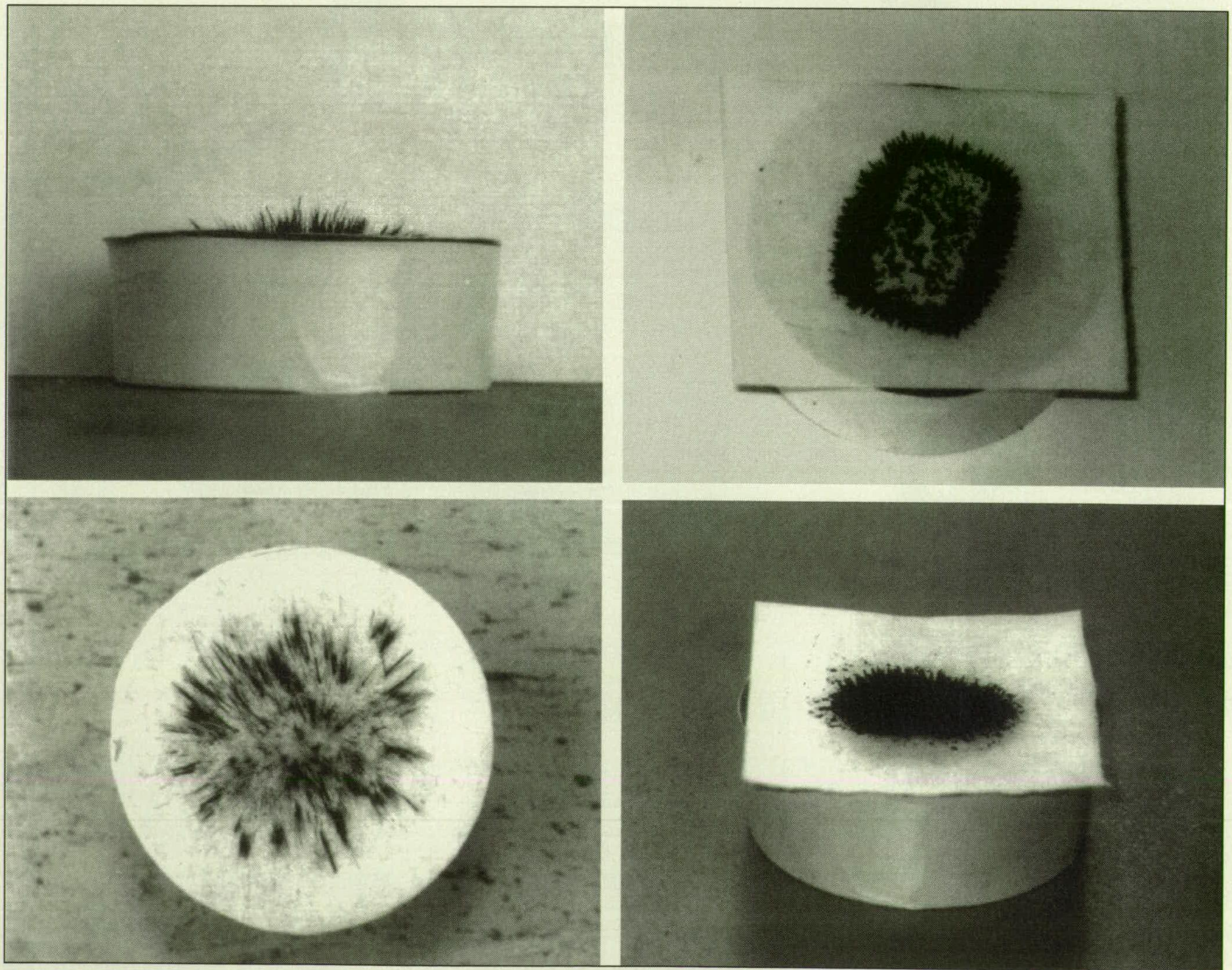
Products can include magnetic materials.

Lewis Research Center, Cleveland, Ohio

Experiments have shown that carbon-based materials containing pure metallic iron, alloys of iron, halides of iron, and/or oxides of iron can be synthesized from precursors of general composition CF_x, denoted loosely as graphite fluoride. Typical samples of the product materials contain 1 iron atom per 3.5 to 5 carbon atoms. Those product materials that contain iron in the pure, alloy, and/or Fe_3O_4 forms are magnetic (see figure).

Some earlier related experiments were reported in "Storing Fluorine in Graphitelike Carbon Fibers" (LEW-15359), *NASA Tech Briefs*, Vol. 19, No. 12 (December 1995), page 63 and "Modification of Carbon Fibers for Higher Young's Modulus" (LEW-15847) *NASA Tech Briefs*, Vol. 21, No. 4 (April 1997), page 56. In other earlier related experiments not reported in *NASA Tech Briefs*, it was found that $FeCl_3$ reacts with CF_x at temperatures between 300 and 400 °C to yield graphite intercalation compounds containing iron chloride or mixtures of iron chloride and fluoride; this finding constitutes the point of departure for the experiments reported here.

The precursor materials used in these experiments were CF_x (x ranging from 0.68 to 1.0) made, variously, from highly graphitized carbon fibers, less-graphitized carbon fibers, nongraphitized carbon fibers, and crystalline graphite pow-



Carbon-Based Material That Contains Fe_3O_4 becomes arranged in the familiar pattern of magnetic-field lines when placed on the face of a permanent magnet. On the left are side and top views of a fibrous sample; on the right are two angle views of a powdered sample.

ders. The experiments included exposure of $CF_{0.68}$ to $FeCl_3$ at temperatures between 280 and 420 °C to study the details of the overall general reaction $CF_x + FeCl_3 \rightarrow C$(iron halides). Between 280 and 295 °C, $FeCl_3$ quickly entered the molecular structure of $CF_{0.68}$ and broke the carbon-fluorine bonds; within 10 to 30 minutes, the $CF_{0.68}$ was completely converted to carbon made of graphite planes, between which particles of crystalline FeF_3 and noncrystalline $FeCl_2$ were located. Longer reaction times (e.g., 28 hours) or higher reaction temperatures (e.g., 420 °C) yielded materials that contained graphite, an $FeCl_3$/graphite intercalation compound, $FeCl_2{\cdot}4H_2O$, and $FeCl_2{\cdot}2H_2O$.

Materials produced in the foregoing reactions were subjected to various further heat treatments — some in air, some in nitrogen. When the heating temperatures were kept between 750 and 850 °C and the oxygen supply was kept at the optimum level, the iron halides were converted to iron oxides. When the heating temperature was increased to 900 °C, the iron oxides were reduced to iron metal. These observations led to further experiments in which, prior to the heat treatments, the materials were mixed with NiO or $NiCl_2$ in attempts to induce the formation of Fe/Ni alloys. In one successful experiment along this line, a commercial $CF_{0.7}$ powder that had been reacted with $FeCl_3$ was mixed with NiO, then the mixture was heated to a temperature of 1,200 °C for 45 minutes in quartz tubes in a nitrogen atmosphere. The product of this experiment was examined by x-ray diffraction and found to be carbon containing an Fe/Ni alloy.

This work was done by Ching-cheh Hung of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 102*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16432.

Fiber-Reinforced-Plastic/Concrete Structural Members

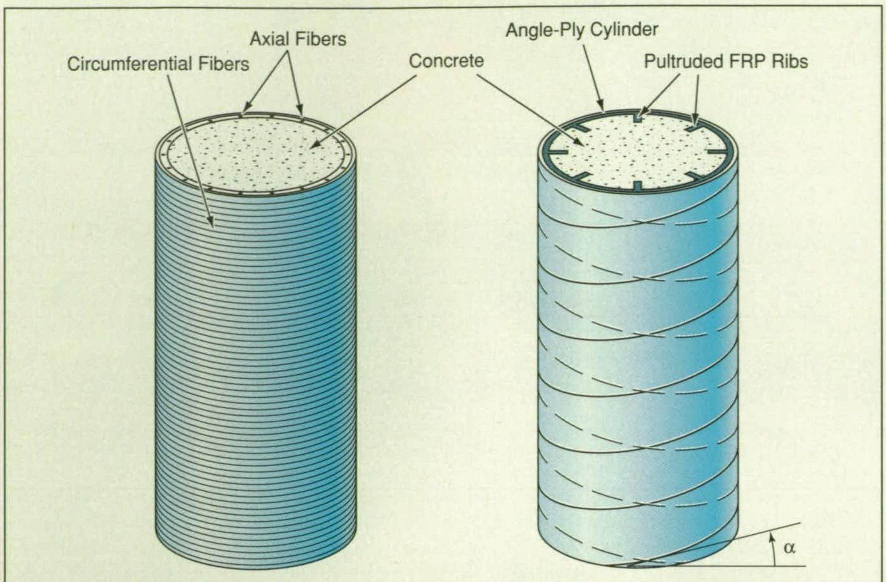
Strength and durability are enhanced.

John F. Kennedy Space Center, Florida

Improved concrete structural members such as columns, piers, and piles can be manufactured by incorporating fiber-reinforced-plastic (FRP) exterior shells and FRP interior submembers. The FRP components impart greater compressive, flexural and shear strengths and ductility to a concrete structural member, relative to a similar concrete structural member made in the conventional way, without FRP. During fabrication, the FRP exterior shell also serves as a form for casting the concrete. Moreover, during use of the structure, the FRP exterior shell prevents or retards the intrusion of moisture, thereby helping to prevent or retard both environmental degradation of the concrete and corrosion of any steel reinforcement or steel structural member(s) embedded or anchored in the concrete. Thus, concrete structural members made with FRP offer greater strength and durability that should be especially advantageous for bridges and similar structures in hurricane-prone coastal areas, earthquake zones, and regions where moist concrete is damaged during freeze/thaw cycles.

Concrete structural members incorporating FRP components can be made in a wide variety of configurations, using a wide variety of polymer-matrix/fiber composite materials and composite-fabrication processes, and various concretes with or without conventional steel or advanced fiber reinforcement. A typical FRP comprises about 60 percent fibers (e.g., glass, carbon, or aromatic polyamid) and 40 percent polymeric matrix material (e.g., a polyester, vinylester, or epoxy). The concrete can be cast at the construction site, or it can be cast in a factory, possibly using centrifugation to enhance the bond between the concrete and the exterior shell.

The figure illustrates some typical configurations for a round column with an FRP tube as the exterior shell, with or without interior FRP reinforcement. The shell can be made in two or more



Concrete Columns can be fabricated with FRP exterior shells. Optionally, FRP ribs or other reinforcing FRP interior components can be included. The two configurations shown here are only typical; many other configurations are also possible.

layers; for example, an inner layer containing axial fibers and an outer layer containing circumferential (hoop) fibers, both layers fabricated in a continuous filament-winding process. The ribs (if any) can be made by pultrusion. The axial fibers (if any) increase the flexural capacity of the column. Inward buckling of the axial fibers is inhibited by the concrete core. The hoop reinforcement confines the concrete and prevents outward bucking of both the axial fibers and of any longitudinal interior reinforcing ribs or bars. Alternatively, the exterior shell can be fabricated in a multilayer angle-ply configuration with winding angles of $\pm\alpha$, or as a sandwich of axial fibers between two hoop layers.

The interior FRP reinforcement can be in any of various forms; for example, ribs or H-columns, or else bars or cages like those of conventional steel reinforcements. A particularly advantageous design calls for pultruded longitudinal ribs formed integrally within a pultruded tube covered by an angle-ply laminate, as shown on the right side of the figure. This design can reduce or even eliminate the need for a conventional steel reinforcing cage embedded in the column, thereby reducing the time and cost of construction and enhancing durability in a saltwater or other corrosive environment.

This work was done by Amir Mirmiran of the University of Central Florida and Moshen Shahawy of the Florida Department of Transportation for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 127*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). KSC-11946*

Creep-Resistant Ceramic Composite for High-Temperature Use

Alumina, silica, and mullite are combined into an improved matrix material.

Lewis Research Center, Cleveland, Ohio

A low-density, creep-resistant ceramic composite material has been developed as a prototype of such materials for use at high temperatures in the next generation of aircraft engines. The material consists of Nextel (or equivalent) ceramic fibers in a matrix that is, itself, a composite of mullite particles in a mixture of 90 percent alumina with 10 percent silica. In fabricating an article of this material, the matrix is infiltrated into a three-dimensional woven fiber preform by use of sol-gel techniques in a multistep process.

In general, it is desirable to prevent bonding between the matrices and fibers of high-temperature ceramic composite articles to prevent fiber/matrix interactions of a type that can damage the fibers and thereby lead to embrittlement and failure of the articles. To prevent matrix/fiber bonding in the present material, an unstabilized zirconia interfacial layer is deposited on the fibers prior to infiltration with matrix material. Subsequently, the zirconia goes through a phase change with a concomitant volume change as it is heated and again as it is cooled. These volume changes fracture the interfacial layer, thus destroying any matrix/fiber bonds that might have formed.

The infiltration steps provide a matrix of uniformly low density. The initial infiltrating matrix precursor material comprises mullite powder mixed into an alumina/silica sol-gel. The viscosity of the gel keeps the mullite powder in suspension during infiltration. (The viscosity of the gel can be temporarily reduced by an ultrasonic probe to aid infiltration.) The sol is then gelled in situ by use of ammonia gas to cause a change in pH. The gelation step helps to ensure uniform distribution of matrix material throughout the preform by preventing the liquid component of the matrix precursor from migrating away from the interior of the article during drying. The article is then heat-treated above the matrix-precursor transition temperature of 526 °F (274 °C).

Further densification is achieved by repeated steps of infiltration with alumina/silica sol-gel followed by heat treatment above the transition temperature. A final heat treatment is performed at the intended use temperature to stabilize the matrix.

In an experiment, the four-point-flexure strength of a specimen of this material was 3.9 kpsi (27 MPa) before and 3.6 kpsi (25 MPa) after exposure to a temperature of 1,800 °F (980 °C) for 100 hours. The corresponding flexure-strength figures for a specimen with an all-alumina matrix were lower; 3.3 kpsi (23 MPa) before and 2 kpsi (14 MPa) after exposure to the same high temperature.

This work was done by Anna L. Baker of United Technologies Pratt & Whitney for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 113*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16248.

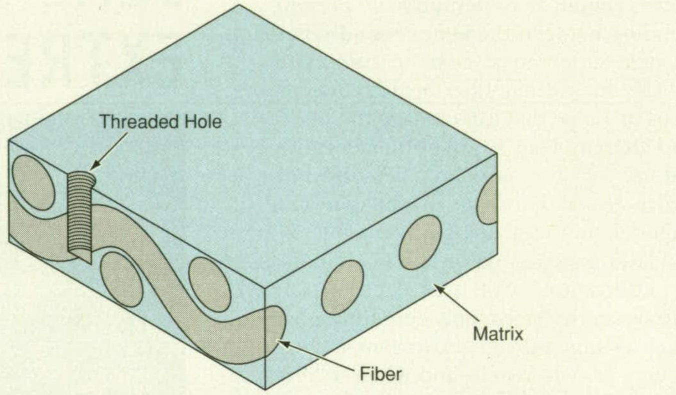
Nearly Isotropic Resin-Transfer-Molded Composites

Unlike older resin-transfer-molded composites, these can be machined in fine detail.

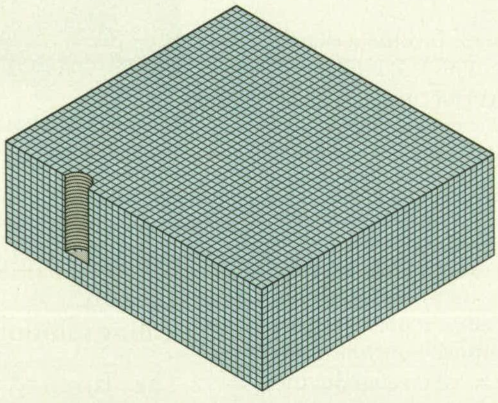
NASA's Jet Propulsion Laboratory, Pasadena, California

Nearly isotropic matrix/fiber composite materials can be made quickly and at relatively low cost by resin-transfer molding. The fiber components of these materials are fine, loosely woven, three-dimensional preforms; the matrix components are epoxy or polycyanate resins. With proper tooling, these materials can be resin-transfer molded to net shape. Alternatively, they can be machined to net shape. The three-dimensional weaves enable the materials to withstand machining with minimal loss of mechanical properties. These materials are particularly suitable for lightweight, all-composite replacements for aluminum end fittings that have been used on tubular composite-material structural members.

Heretofore, resin-transfer-molded composites have been made with relatively coarse three-dimensional braided or angle-interlock woven preforms (see figure). These composites are so coarse that they cannot be machined and cannot be fabricated with fine details. For example, screw threads in these materials are useless because the threads contain no reinforcement and thus have insufficient strength.



OLDER-STYLE COMPOSITE BLOCK CONTAINING PREFORM WITH COARSE BRAID



NEWER-STYLE COMPOSITE BLOCK CONTAINING PREFORM WITH FINE WEAVE

The **Fine Weave** of the newer composite is more conducive to fine machining and to retention of strength in fine details like screw threads.

The fine three-dimensional weaves of the present composites were developed previously for carbon/carbon composites, but have not been used heretofore in resin-transfer-molded composites. The method used heretofore to make carbon/carbon composites requires long processing times and expensive capital equipment, and the materials produced by this method are too brittle at room temperature to satisfy the requirements that prompted the devel-

opment of the present nearly isotropic resin-transfer-molded materials.

The three-dimensional loosely woven preforms used in the present materials cost less than do the coarser three-dimensional preforms made by conventional three-dimensional braiding or weaving. In comparison with the coarser three-dimensional woven preforms, the present finer preforms are weaker on a large scale but stronger on a small scale like that of screw threads, where the fine weaves provide reinforcement that the coarser weaves cannot.

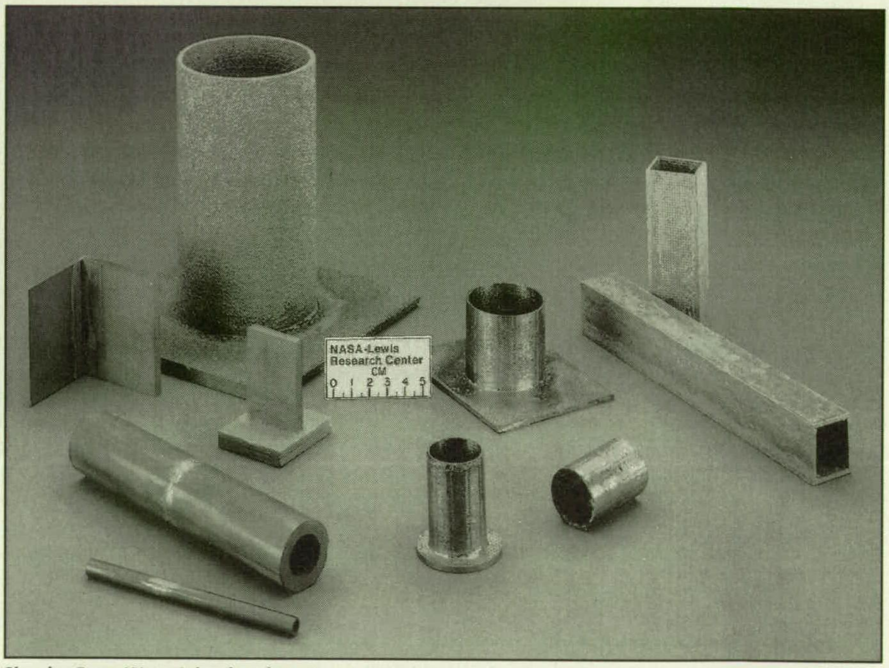
This work was done by D. Kyle Brown of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 103*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-19918*

Joining of SiC-Based Ceramic and Fiber-Reinforced Composite Parts

Thermomechanical properties of joints can be tailored.

Lewis Research Center, Cleveland, Ohio

A process that involves reaction forming has been devised to enable the joining of high-temperature-resistant structural parts made of SiC-based materials. These materials include SiC-based ceramics and composites reinforced by fibers that are made of various component materials and are woven, wound, or otherwise arranged in various configurations. The technique can be used to join simply shaped parts to make complexly shaped structures, and to repair such parts and structures.



Simpler Parts Were Joined to form more-complex parts by the joining process described in the text.

The process begins with the application of a carbonaceous mixture to the joint regions between parts. The mixture is cured at a temperature between 90 and 110 °C. The joints are then locally infiltrated with molten silicon or with alloy(s) of silicon and refractory metal(s). The molten silicon or alloy reacts with the carbon in the joint to form silicon carbide with amounts of silicon and refractory disilicide phases that can be tailored by choice of the compositions of the reactants. Consequently, the process results in joints with tailorable microstructures and thus tailorable thermomechanical properties. The properties of the joints can be tailored to approximate closely those of the joined parts.

The figure shows some examples of SiC-based ceramic and fiber-reinforced composite parts that were joined by use of this process. In mechanical tests, the joints on these parts were found to retain their strength at temperatures

from ambient up to 1,370 °C. The test temperature of 1,370 °C is above the maximum to which the parts are expected to be exposed in use.

This work was done by Mrityunjay Singh of NYMA, Inc., for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 157*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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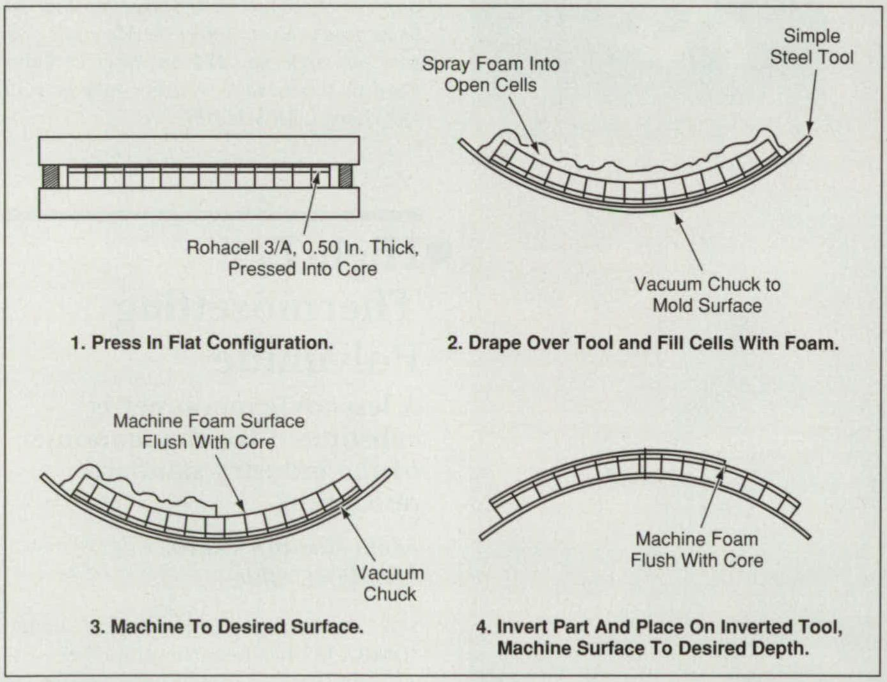
Advanced Cryogenic Insulation System for Graphite/Organic Resin Composite Cryogenic-Tank Structures

Foam-filled honeycomb cores withstand tensile strain test in cryogenic conditions.

Marshall Space Flight Center, Alabama

Engineers at Rockwell International Corporation's Space System Division have developed a new method of insulating composite structural material that will stand up to the harsh environment of space. The new liquid-hydrogen cryogenic tankage proposed for advanced launch systems — such as the Reusable Launch Vehicle and the X-33 — will be made from a graphite/epoxy material. Although this composite material will produce a lighter-weight cryogenic insulation tank, current cryogenic insulation materials did not endure rigorous stress testing.



Manufacturing Sequence for installing foam into honeycomb core.

Conventional cryogenic tankage (such as the external tank of the space shuttle, and those used on the Saturn SII, SIVB, and Atlas Centaur) are commonly made of aluminum or stainless-steel alloys. Cryogenic insulation materials for these types of tanks consist of monolithic forms of polyurethane foam or an organic spray-on or bonded insulation. These rigid insulation materials proved to be incompatible with graphite composite material at –423 °F (–253 °C) — the cryogenic temperature of liquid hydrogen.

Rockwell engineers called upon previous experience with bonding honeycomb cores to graphite fiber/resin matrix composites, knowing that honeycomb core materials will allow for subtle shifts in the composite and insulation material without bond or shear failure. This "flexibility" is possible because of the accordionlike construction of the

honeycomb core and good adhesion to the composite material.

Cryogenic-tank insulation systems for future launch vehicles also called for insulation that could withstand a maximum 400 °F (204 °C) at the thermal-protection-system interface. Additionally, the core/foam/composite interfaces at the tank wall must be sealed to prevent cryo-pumping.

Because no current pour or spray-in-place insulation materials were available to meet these requirements, engineers decided to combine a 2.0-lb/ft^3 (32-kg/m^3) polymethacrylimide foam sheet (Rohacell 31A or equivalent) with a 2.0-lb/ft^3 (32-kg/m^3) polyurethane spray foam (PDL 1034-141B or equivalent) for temperatures less than 300 °F (150 °C).

This foam combination is accomplished by pressing the Rohacell 31A sheet into the knife edges of one side of the honeycomb core like a cookie cutter. The foam is pressed to the predetermined 300 °F (150 °C) interface. The partially filled core is then inverted, with the bare cells facing up. Next, the Rohacell 31A foam surface is edge-sealed and vacuum-chucked to a curved tool surface representing the curvature of the tank wall. The open cells are then filled with polyurethane spray foam using standard Gussmer pumps and Binks mixing gun equipment. The excess foam material is machined flush with the core cells to the tank contour while still under vacuum from the spray-foam operation. This insulation assembly is then inverted, vacuum chucked to the contour of the convex tool surface, and machined to the final interface contour and thickness.

The completed insulation panels are bonded to the tank-wall surface with a polyurethane adhesive that cures at room temperature (Crest 212 modified with silane Z6040 coupling agent or equivalent). The bonding process involves vacuum-bagging the insulation panel directly to the tank wall and curing the adhesive for at least eight hours prior to releasing the pressure. The total cure time of the adhesive at room temperature is 48 hours.

The process of forming and testing this advanced cryogenic insulation system has been recorded on a videotape, titled "Composite Hydrogen Tank Foam Process for SSTO," tape number 1-9506-09.

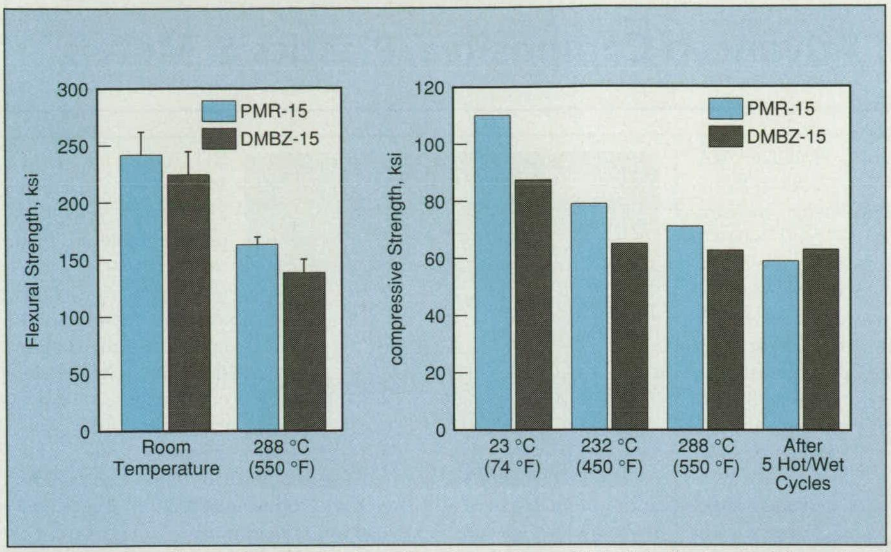
This work was done by Jeff D. Eichinger, Richard G. Jackson, John (Jack) S. Jones, Conley S. Thatcher, and Dave Wittman of Rockwell International Corporation for the **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 175*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). MFS-31108*

High-T_g Thermosetting Polyimide

A less-toxic monomer is substituted for the monomer of the industry standard polyimide.

Lewis Research Center, Cleveland, Ohio

A thermosetting polyimide called "DMBZ-15" has been developed for use as a matrix material in relatively inexpensive matrix/fiber composite materials. The glass-transition temperature (T_g) of DMBZ-15 is 414 °C. In contrast, the industry standard polyimide for such composites (developed in 1971 at Lewis Research center and known as "PMR-15") has a T_g of 348 °C. Because of its higher T_g, DMBZ-15 is better suited for high-temperature use in automotive and aerospace applications.



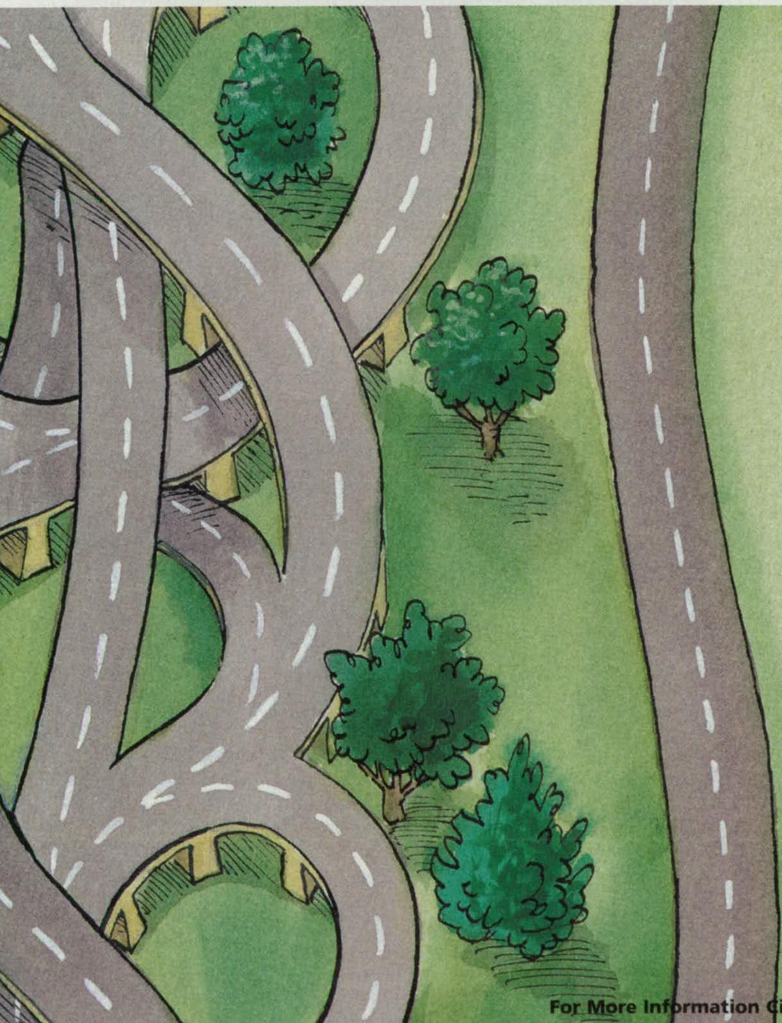
DMBZ-15/Carbon Fiber and PMR-15/Carbon Fiber Composites exhibited similar levels of flexural and compressive strengths.

The development of DMBZ-15 began as a search for an alternative to the toxic monomer — methylene dianiline (MDA) — used to make PMR-15. The objective of the search was to substitute a more benign diamine for MDA, while maintaining composite-material performance comparable to that of composites made with PMR-15. The search led to the ingredients of DMBZ-15; namely, dimethyl ester of 3,3´,4,4´-benzophenone tetracarboxylic acid (BTDE) and 2,2´-dimethylbenzidine (DMBZ) with nadic ester (NE) as the end cap.

Experiments were performed on composite material specimens made with PMR-15 and DMBZ-15 matrices, respectively, reinforced with carbon fibers known by the trade name "T650-35." In one set of experiments, flexural strengths were measured at room temperature and at 550 °F (288 °C). In another set of experiments, compressive strengths were measured at various temperatures up to 550°F (288 ° C). In still another set of experiments, measurements of compressive strength were performed after five "hot/wet" cycles; each cycle comprised (1) a soak in water at 200 °F (93 °C) until a weight gain >1 percent was detected, followed by (2) drying at a temperature of 500 °F (260 °C) until the moisture level was reduced to <0.1 percent of the specimen weight. As shown in the figure, specimens of the two composites tested under the same conditions exhibited comparable levels of flexural and compressive strengths.

This work was done by Kathy C. Chuang of **Lewis Research Center**, *Joseph E. Waters of Case Western Reserve University, and DeNise Hardy-Green of the University of Akron. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16560.

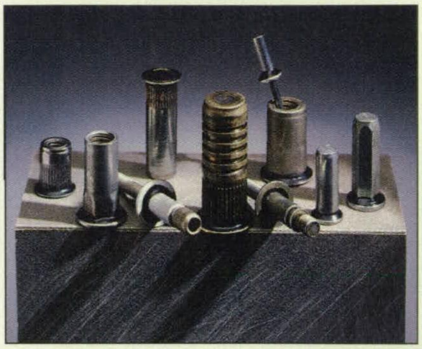


Special Coverage: Advanced Composites, Plastics & Metals

Stevens Urethane, Holyoke, MA, has introduced two grades of flame-resistant **thermoplastic polyurethane.** The ST-1796 and ST-1776 meet UL-94-VTM-O standards for flame-resistance and are designed for applications requiring flame-resistant thin films. ST-1796 features a standard VTM-O package using an antimony oxide synergist with halogen-based flame retardant; the ST-1776 features an alternate non-halogen FR system.

Blown film and extruded sheet are available in thicknesses from 0.001" to 0.125", and in widths up to 80". Tubing, cord, and profile extrusions also are available, as well as a variety of colors, opacities, and surface textures. The polyurethane can be custom-formulated for specific requirements.

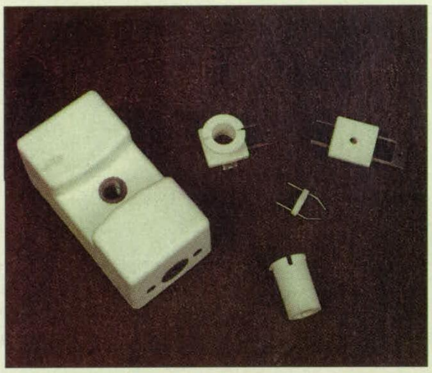
For More Information Circle No. 753



ND Industries, Troy, MI, offers Plastisol PVC **liquid vinyl dispersion material** that can be fused to a fastener by externally applied heat. When applied on the underside of a variety of rivets, it seals against air, water, and dirt, and absorbs noise and vibration. The material can be formulated and altered to produce a soft foam or a dense, hard solid, which stays flexible at low temperatures.

Plastisol can be formulated to resist chemicals, is self-extinguishing, and resists weather. Colors range from clear to virtually any color, including fluorescents. The material features a tensile strength of 750 to 3000 PSI, an application temperature range from -40°F to 250°F, and a hardness of 30 to 90 Shore A.

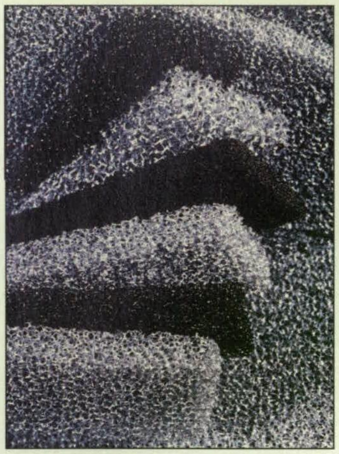
For More Information Circle No. 748



Mykroy/Mycalex Grade 561 high-temperature **glass-bonded ceramic material** from Spaulding Composites, Rochester, NH, is a mica ceramic that withstands operating temperatures to 1400°F. The material offers dimensional stability, the ability to hold metal inserts in molded parts, and the ability to maintain critical part tolerances.

Also available are NEMA G-7 silicon glass tubing, a convolutedly-wound, silicon-impregnated, glass-reinforced material that is rated at 465°F; and Grade LF-1127 lube-free rotor vane material that eliminates the need for oil lubricants. The LF-1127 is a composite laminate material designed with internal lubrication.

For More Information Circle No. 749



Goodfellow Corporation, Berwyn, PA, has introduced an **aluminum alloy foam** made of alloy 6101. The true metal foam is similar to natural sponge in appearance, yet retains its alloy characteristics. It is corrosion-resistant, intrinsically strong, and is thermally and electrically conductive. The foam offers low density of 0.08 to 0.32 g/cm^{-3}, of which 3 to 12 percent is solid aluminum.

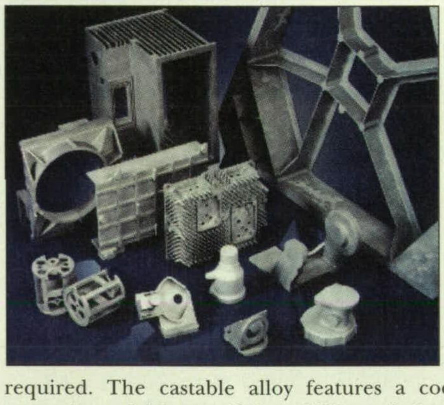
The foam features high strength-to-weight ratio, high porosity, and large surface area. Also offered is pure aluminum as microfoil, microleaf, foil, honeycomb, sputtering target, mesh, wire, insulated wire, rod, tube, powder, lump, and single crystal.

For More Information Circle No. 751

Loctite Corporation, Rocky Hill, CT, offers Durabond 105CL fast-setting, medium-viscosity, two-part industrial-grade **epoxy adhesive** for applications such as flex circuits, cable boots, and staking fillet bonds. The adhesive bonds plastic, metal, glass, wood, ceramic, rubber, and masonry materials while retaining flexibility.

The adhesive sets at room temperature with low shrinkage, and forms a clear bond line. When fully set, it is resistant to chemicals and solvents, and acts as an electrical insulator.

For More Information Circle No. 750



Beralcast® 191 **beryllium-aluminum alloy** from Starmet Corporation, Concord, MA, is designed for producing net shape investment casting electronic heat exchanger and electro-optical components where light weight and thermal conductivity are required. The castable alloy features a coefficient of thermal expansion of 12 ppm/°C at 25°C, and thermal conductivity of 190 W/m-K.

The alloy is 22 percent lighter than aluminum, and exhibits a Young's Modulus of 29.3 mpsi. It has a density of 0.077 lb/in^3, tensile strength of 28.5 ksi, yield strength of 23 ksi, and 2% ductility.

For More Information Circle No. 752

Electronic Components and Circuits

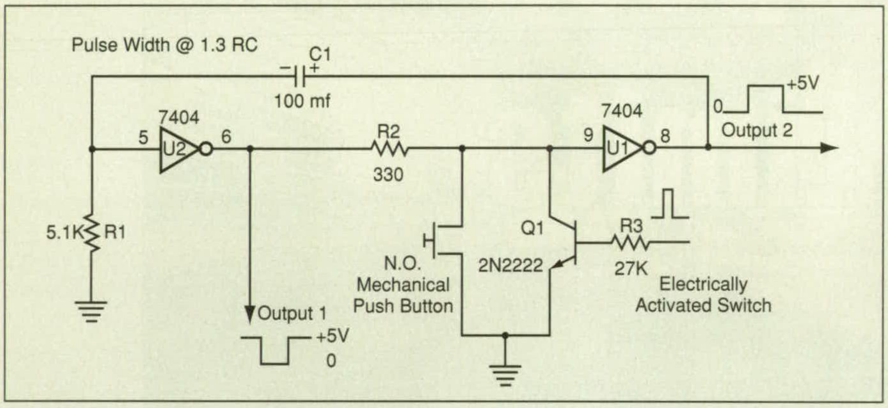
Bounceless Switch/Monostable Multivibrator

Monostable circuit debounces a switch while allowing for the monostable circuit to be activated by an electronic circuit.

Marshall Space Flight Center, Alabama

A circuit has been designed to debounce a mechanical switch, which is used to activate a digital circuit. Contacts tend to make and break connections several times until the switch contacts settle out. The repetitive activity plays havoc with digital circuits because more than one state condition could be activated by the switch as it bounces around between state conditions.

The switch debouncer circuit will recognize the first state condition activated by the switch and latch the circuit into this condition for a predetermined period of time until the switch bouncing settles down. In this way, the circuit will respond to only one pulse generation performed by the depressing of the switch and not several state transitions caused by contact bouncing.



A **Monostable Multivibrator** generates a single pulse output when activated by a trigger command.

This circuit can also be used for a monostable multivibrator or one-shot multivibrator. A monostable multivibrator generates a single pulse output when activated by a trigger command. The pulse width or pulse duration in this circuit is defined by selecting the proper values of a resistor and capacitor arrangement.

This work was done by Randal S. McNichol of the **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 111*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
MFS-31141

Exploiting Brillouin Scattering in Analog Signal Processing

Heretofore a nuisance, this phenomenon can be used for amplification and frequency conversion.

NASA's Jet Propulsion Laboratory, Pasadena, California

Stimulated Brillouin Scattering (SBS) in optical fibers can be exploited to obtain frequency conversion with amplification and frequency-selective amplification in photonic signal-transmission and signal-processing systems. SBS has been found to be particularly useful in photonic systems that handle optical carrier signals modulated with relatively narrow-band radio-frequency (RF) signals that are typically of analog origin.

Brillouin scattering is the scattering of photons by phonons. It can occur spontaneously at low optical power levels and can be stimulated by narrow-band optical signals above threshold power levels that can be as low as a few milliwatts in some optical fibers. Because the threshold power for SBS in an optical fiber is proportional to the spectral width of the input optical signal, SBS does little harm in digital communication systems, in which bandwidths are typically large and power levels of the order of microwatts usually suffice to achieve adequate signal-to-noise ratios. However, in analog communication systems, spectral widths are smaller and power levels of the order of milliwatts are usually needed, so that SBS becomes an issue.

SBS is the most sensitive nonlinear optical effect in optical fibers. At a signal power level above the threshold in a given fiber, SBS generates an acoustic grating via the electrostrictive effect, and the grating gives rise to back-scattering of the forward-propagating optical signal. The back-scattering limits the forward-propagating optical power that can be delivered to the output end of the fiber; in other words, the net effect is one of throughput saturation. Thus, heretofore, SBS has been regarded as a nuisance in narrow-band photonic/RF communication systems.

Experiments have shown that when a single-frequency optical signal is launched into an optical fiber, SBS typically occurs with a spectral peak at frequency of the order of a few gigahertz below the signal frequency, and the 6-dB width of the SBS spectrum is typically of the order of 10 MHz. The experiments have also shown that for a given fiber, the SBS peak frequency and spectral width are independent of the signal power. These findings point the way to the use of a single-frequency

optical signal as a pump signal in a scheme to achieve frequency-selective amplification, as described next.

The upper part of the figure schematically illustrates a laboratory SBS amplification apparatus, while the lower part of the figure depicts the spectral peaks present during operation. A pump signal is generated by an yttrium/aluminum/garnet (YAG) laser at a wavelength of 1,320 nm and coupled into one end of a 12.8-km-long optical fiber. Another YAG laser generates a carrier signal; this signal is amplitude-modulated with an RF signal (by use of a $LiNbO_3$ Mach-Zehnder Modulator) and coupled into the other end of the long optical fiber. The apparatus is designed to minimize reflections. The back-scattered optical power is sampled via port 2 of a four-port fiber-optic coupler, while the input (forward-propagating) pump power is sampled via port 4 of the coupler.

The pump or the carrier laser is adjusted so that the frequency of the carrier signal is lower than that of the pump signal by such an amount as to place the lower sideband of the modulated signal at the SBS peak. As a result, the lower sideband joins the back-scattered signal and becomes amplified by the nonlinear SBS effect. The amount of amplification diminishes gradually with departure of frequency from the SBS peak. The carrier and lower sideband are sufficiently distant in frequency from the SBS peak that they are not amplified.

Frequency conversion with amplification can be effected by an apparatus that is similar except that the modulator includes two independent RF input ports with a high degree of mutual isolation. RF modulation is coupled in through one port, while a local-oscillator (LO) signal is coupled in through the other port. The pump and carrier frequencies are adjusted to place the lower LO sideband at the SBS frequency so that the LO signal becomes amplified. The amplified LO signal is then mixed with the RF sidebands to obtain stronger up- and down-converted signals. Optionally, one could choose the frequencies to amplify the lower RF modulation sideband instead of the lower LO sideband, but in that case, the RF-amplification bandwidth would be limited by the SBS bandwidth.

This work was done by Xiaotian Steve Yao of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 153*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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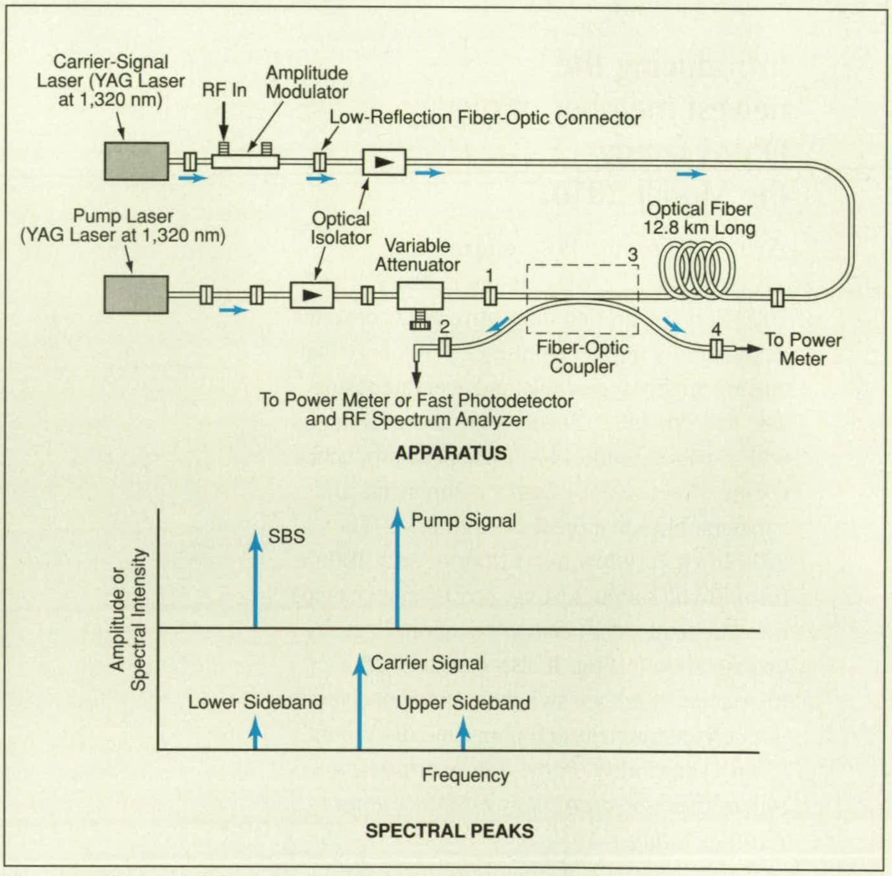


The **Lower Sideband** of the optical carrier signal as modulated by the RF signal is made to coincide in frequency with the SBS peak. As a result, the lower sideband is amplified by SBS.

More Uses for Brillouin Amplification

Phase modulation can be converted to amplitude modulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Some additional applications have been proposed to exploit amplification by stimulated Brillouin scattering ("Brillouin Amplification" for short), building on the concepts introduced in the preceding article. Chief among the proposed applications is conversion of a phase-modulated optical signal to an amplitude-modulated optical or electrical signal with stability greater than that previously achievable, and without need for bias.

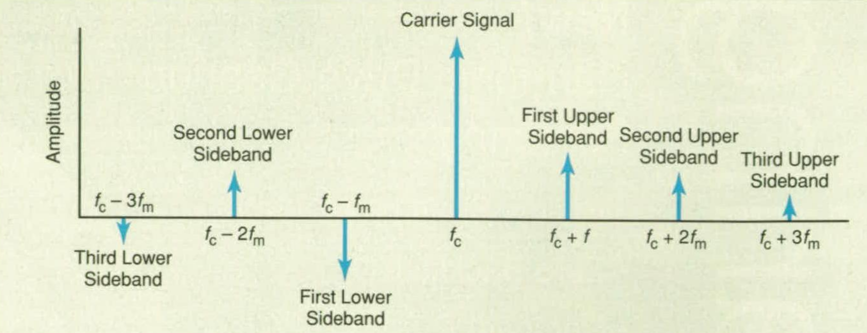
The difficulty of converting a phase-modulated optical signal to an amplitude-modulated optical or electrical signal arises from the essential nature of any phase-modulated signal. As illustrated in Figure 1, a phase-modulated signal includes many pairs of sidebands at integer multiples of the modulation frequency, f_m, above and below the carrier frequency. For each upper sideband, there is a corresponding lower sideband of equal magnitude, and the

difference between the phases of the upper sideband and the carrier is the opposite of the difference between the phases of the lower sideband and the carrier. One cannot obtain amplitude modulation through the mere detection of the phase-modulated signal because the symmetry between the upper and lower sidebands gives rise to a corresponding symmetry in the beat notes among all the sidebands and between the sidebands and the carrier.

The chief proposal for converting phase modulation to amplitude modulation involves the use of frequency-selective amplification of one of the lower sidebands to break the symmetry between this sideband and its corresponding upper sideband. Brillouin amplification offers the frequency selectivity needed for this purpose. For example, as illustrated in Figure 2, one could adjust the pump and carrier frequencies to place the first lower sideband at the Brillouin-scattering spectral peak. This adjustment would cause the first lower sideband (but not the carrier or the first upper sideband) to become Brillouin-amplified, as described in the preceding article. The beat between the carrier and the preferentially amplified first lower sideband would constitute the major part of the amplitude-modulated output signal. The amplitude modulation would be extremely stable in that it would be immune to fluctuations in the carrier frequency, the temperature, and the length of the optical fiber. In addition, the Brillouin amplification of the chosen sideband would make this technique the most efficient of all techniques for phase-to-amplitude conversion.

Other proposed applications of Brillouin amplification for conversion from phase to amplitude modulation include photonic frequency conversion, photonic frequency multiplexing, photonic generation of harmonics, and photonic amplification and shaping of optical pulses. The pulse application would be the most complex because it would involve the use of multiple pump lasers to achieve Brillouin amplification at multiple selected sidebands of a phase-modulated signal or at multiple modes of a mode-locked laser.

This work was done by Xiaotian Steve Yao of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 154*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*



$$
\begin{aligned}
S(t) &= A\cos\,[\omega t + \delta\sin\,\omega_m t] \\
&= A[J_0(\delta)\cos\,\omega t + J_1(\delta)\cos\,(\omega + \omega_m)t - J_1(\delta)\cos\,(\omega - \omega_m)t \\
&\quad + J_2(\delta)\cos\,(\omega + 2\omega_m)t\ + J_2(\delta)\cos\,(\omega - 2\omega_m)t \\
&\quad + J_3(\delta)\cos\,(\omega + 3\omega_m)t\ + J_3(\delta)\cos\,(\omega - 3\omega_m)t \\
&\quad + J_4(\delta)\cos\,(\omega + 4\omega_m)t\ + J_4(\delta)\cos\,(\omega - 4\omega_m)t + \ldots]
\end{aligned}
$$

Figure 1. The **Spectral Symmetry** of a phase-modulated signal precludes extraction of amplitude modulation via beat notes and simple detection. Here S is the instantaneous signal amplitude, t is time, $\omega = 2\pi f_c$ where f_c is the carrier frequency, $\omega_m = 2\pi f_m$, δ is the maximum phase deviation, and J_i (i an integer) denotes a Bessel function.

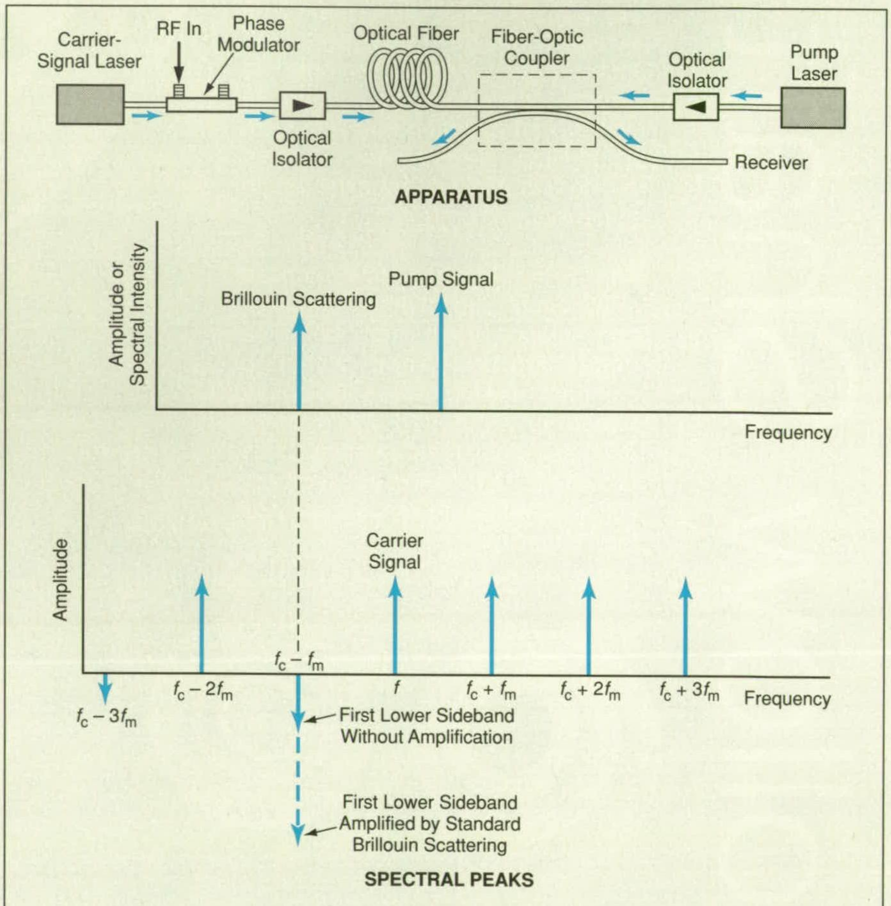


Figure 2. **Phase Modulation Would Be Converted** to amplitude modulation as follows: The first lower sideband of the phase-modulated signal would be Brillouin-amplified, then detected to obtain amplitude modulation in the form of the beat note between the carrier and the first lower sideband.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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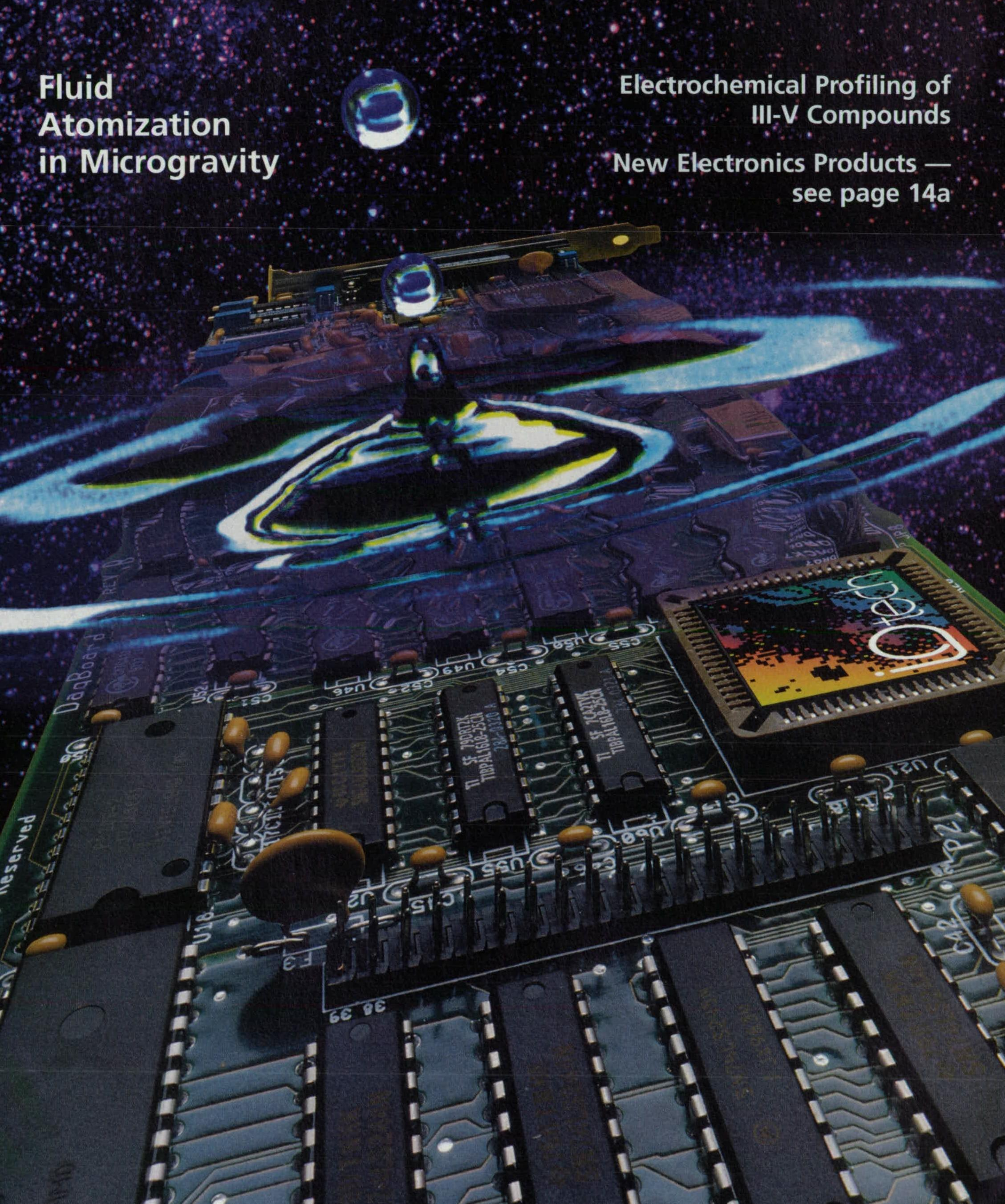
May 1998

Electronics TECH BRIEFS

Fluid Atomization in Microgravity

Electrochemical Profiling of III-V Compounds

New Electronics Products — see page 14a



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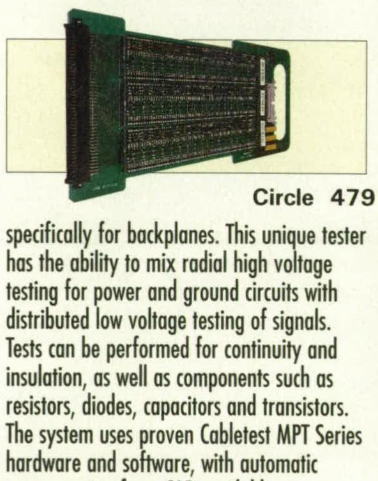

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NEWS BRIEFS

Notes from Industry and the Federal Laboratories

Silicon Graphics of Mountain View, CA, and **Microsoft** of Redmond, WA, announced a strategic alliance aimed at increasing graphics capabilities for consumer, business, and professional customers. The intention is to draw upon each company's expertise to significantly advance graphics technology and create a common extensible architecture that will bring advanced graphics to the entire computer market. The companies have agreed to define, develop, and deliver these new graphics technologies as part of a project code-named "Fahrenheit."

The Fahrenheit project will create a suite of application programming interfaces (APIs) for the Microsoft DirectX® multimedia architecture on the Windows® operating system and the Silicon Graphics® UNIX-based platform. Fahrenheit will incorporate Microsoft Direct3D® and DirectDraw® APIs with Silicon Graphics' complementary technologies such as OpenGL®, OpenGL Scene Graph™, and OpenGL Optimizer™. The Fahrenheit architecture will be the basis for innovative third-party graphics and visualization applications, including Internet, games, business, digital content creation, CAD/CAM, medical, and scientific applications.

The Fahrenheit APIs will be developed in conjunction with software and hardware development partners in an open design preview process during which input will be solicited from all interested parties. In particular, Microsoft and Silicon Graphics will work together with industry representatives, including Intel Corp., to evolve the APIs. Specifically, Intel will work with the partners on the Fahrenheit low-level API to ensure maximum support of the Intel Pentium II processor.

Cognex Corp. of Natick, MA, has received a purchase order for approximately \$1 million from **F&K Delvotec Bondtechnik GmbH**, a manufacturer of semiconductor production equipment in Ottobrunn, Germany. The Cognex 5000 Series machine vision systems were scheduled to ship from the present through the middle of 1999. F&K Delvotec integrates the Cognex vision systems into its die and wire bonding equipment, which is used to automatically attach semiconductor die to leadframes, printed circuit boards, and ceramic substrates. On die bonders, the vision system inspects the site before the die is placed on it, guides a robotic gripper in picking and placing the die, and inspects it afterward for proper bonding. On wire bonders, the system guides the connection of ultrathin wires between semiconductors and leadframes.

Pacific Northwest National Laboratory of Richland, WA, will team with **SEMATECH** of Austin, TX, to develop new materials to meet the high performance needs of next-generation semiconductor devices, including advanced microprocessors. Through the \$1.5-million project, the collaborators will investigate using mesoporous silica as an improved insulating material between metal conduction lines on semiconductor chips. Porous and uniform in structure, the material can be formed into thin films, potentially resulting in semiconductor devices that operate at much higher speeds yet consume less power than today's. The new material is also expected to cut fabrication costs, perhaps as much as \$500 million annually. The Department of Energy and SEMATECH will split the total costs over a period of three years.

For More Information Circle No. 460

Getting Close to FLUID ATOMIZATION IN SPACE

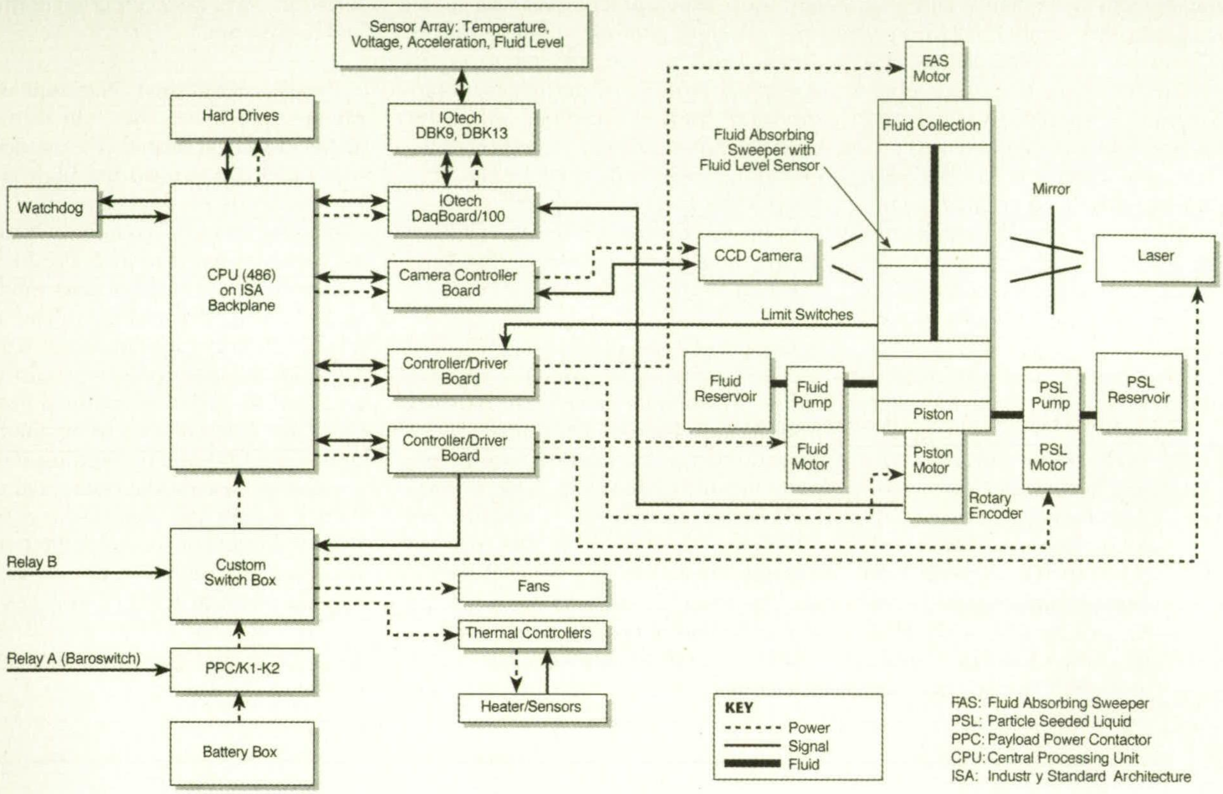


Figure 1. Inside the Get-Away Special Vortex Experiment Instrumentation.

The recent Space Shuttle Endeavour mission called STS-89 included a payload experiment (G-093) to investigate fluid atomization, a process relevant to many Earth-based design and manufacturing applications. Also known as the Vortex Ring Transit Experiment (VORTEX), G-093 was designed by the University of Michigan Students for the Exploration and Development of Space (UMSEDS) to study the physics of fluid atomization in microgravity.

More specifically, VORTEX is investigating the propagation of a vortex ring through a liquid-gas interface in microgravity. As the vortex ring propagates through the interface, it forms one or more drops. The scientific objective is to observe the liquid-drop formation process in the case of surface-tension-dominated interface dynamics. Microgravity makes it possible to examine these dynamics in large drops, enabling a much more detailed observation than is possible on Earth. Data collected from VORTEX should lead to better methods for fluid atomization, important in the design and operation of internal combustion engines, for inert gas atomization, which is vital in powder metallurgy, and for encapsulating drops of complex structures, which are key to pharmaceutical developments.

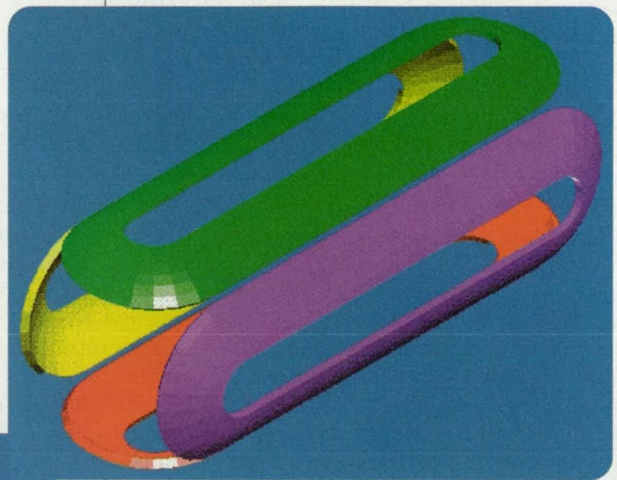
One of the main results expected from VORTEX is the critical Weber number for drop formation. The Weber number—the ratio of inertia force to surface-tension force—is the controlling parameter of the experiments. The critical Weber number is defined as the minimum Weber number for which a drop forms. Experiments on Earth under simulated microgravity conditions and numerical simulations provide estimates of the critical Weber number. The Earth-based experiments, however, used density-matched liquids to minimize the effect of gravitational force. In most atomization systems the density change across the interface is large, typically 1000:1 for a liquid-gas system. VORTEX will provide the first data on the critical Weber number for large density change across the interface.

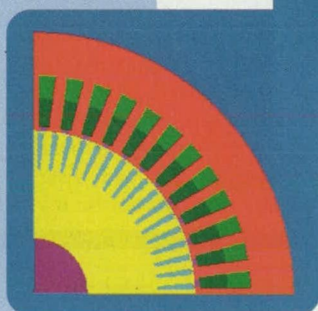
STUDYING SATELLITE DROPS

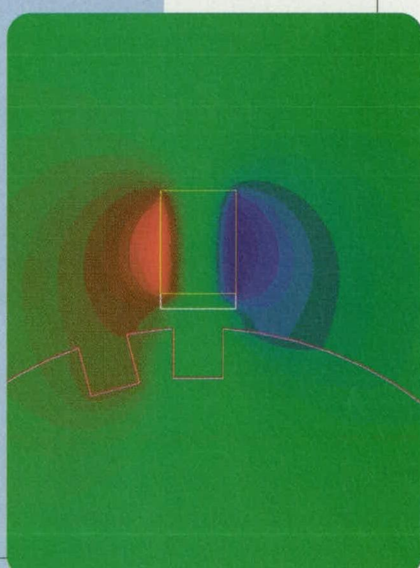
Another interesting phenomenon observed in ground-based experiments is the formation of smaller, or satellite, drops during the interaction. For a small range of Weber numbers above the critical value, the ground-based experiments show that smaller drops accumulate along the elongated liquid column that forms during the interaction. Numerical simulations and the ground-based flow visualization results suggest that the satellite-drops-formation mechanism is very sensitive to small changes of the flow parameters. VORTEX should provide new data on the formation of such satellite drops and the significance of density change across the interface in the process.

VORTEX flow visualization results will also be used to validate numerical simulation of the flow. Such numerical simulation of the flow in the VORTEX experiment is a particularly challenging task. Large deformations of the liquid-gas interface are produced, and the interface breaks one or more times to form drops. VORTEX will provide data to validate the numerical models used to compute the flow efficiently and the results.

Weighing less than 185 pounds, the VORTEX experiment is housed in a 5-cubic-foot canister that is manufactured by NASA. The experiment's main components include a test-cell system, laser-







based illumination, a charge-coupled-device (CCD) digital imaging system, and computer-based data acquisition. This last system comprises an IOtech DaqBoard/100, a DBK9 resistance temperature detector (RTD) measurement card connected to eight RTD sensors to record operating temperatures in eight zones, and a DBK13 high-gain analog input card to capture acceleration readings, fluid levels, and bus voltages via an infrared reflector in the fluid test cell.

During the experiment (see Figure 1), the fluid test cell is partially filled with a silicone oil to establish the liquid-gas interface. The vortex ring generator, which is located at the bottom of the test cell, consists of a piston moving inside a cylindrical cavity. In the test process, the piston lowers itself in the cylinder, at which point the cylinder is filled with the oil, seeded with silver-coated hollow glass microspheres. The piston's rapid upward motion generates the vortex ring, which propagates to the liquid-gas interface. The laser system illuminates a

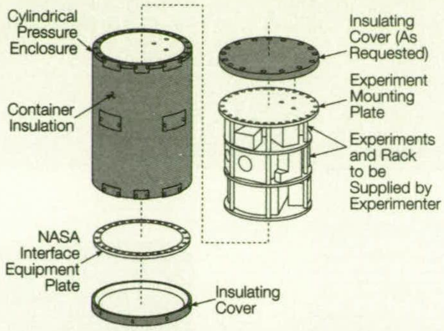


Figure 2. Get-Away Special Small Self-Contained Payload Container Concept.

cross section of the fluid cell, and the CCD camera captures digital images of the fluid motion and the fluid formation process. The data acquisition system simultaneously records the liquid temperature in eight zones, and the acceleration in the fluid test cell. All data is stored on hard disk for analysis by UMSEDS after the canister is returned to Earth.

VORTEX was part of the Get-Away Special (GAS) program, organized by NASA to give corporations and educational institutions opportunities to develop space shuttle payload experiments. Organizations may perform their experiments on any educational or scientific topic as long as they pass NASA safety reviews. All GAS payload experiments must weigh less than 200 lbs. and must fit in NASA's 5-cubic-foot GAS canister (Figure 2). There is a $10,000 participation fee for educational institutions. Foreign and corporate institutions are able to participate in the program for $27,000.

The UMSEDS VORTEX project is being supported by equipment donations from IOtech Inc. (data acquisition board and signal conditioning cards); Minco Corp. (RTD sensors); Hewlett Packard Co. (test and measurement suite); Nematron (flight and ground support computer); and Tektronix Inc. (handheld oscilloscope). Financial donations were provided by General Motors Corp., Hewlett Packard, TRW, the Michigan Space Grant Consortium, and numerous University of Michigan departments.

For more information about VORTEX, please contact Sven Bilén, Project Manager, 2455 Hayward St., Ann Arbor, MI 48109-2143; phone: (734) 763-5357; E-mail: sbilen@umich.edu. For more information about IOtech's data acquisition applications, contact IOtech Inc., 25971 Cannon Rd., Cleveland, OH 44146; phone (440) 439-4091; World Wide Web: http://www.iotech.com.

***On the cover:** Shown is an artist's conception of the VORTEX experiment to study the fluid atomization in microgravity. Image courtesy IOtech Inc.*

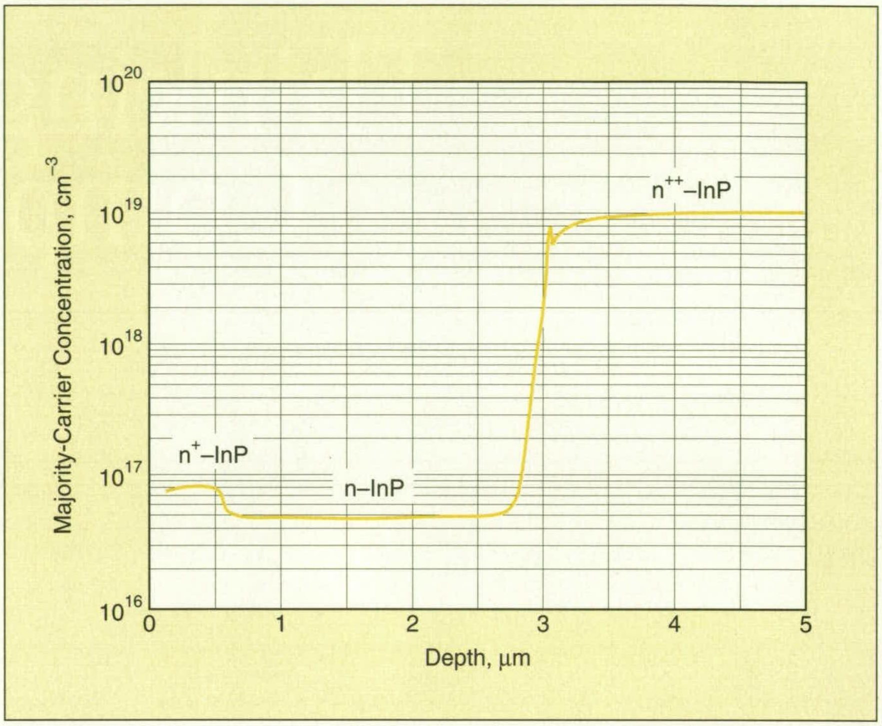
Better Electrochemical Profiling of III–V Semiconductors

An improved solution can be used on a greater variety of materials.

Lewis Research Center, Cleveland, Ohio

An etching and electrolyte solution called "UNIEL" has been found to be useful for electrochemical characterization as a function of depth ("electrochemical profiling" for short) of semiconductor compounds of elements from periods III and V of the periodic table; that is, InP- and GaAs-based semiconductors. UNIEL is a mixture of three solutions denoted A, B, and C in the volume proportions of 1, 4, and 1, respectively. The compositions of these solutions are the following:

- Solution A: 5 parts by volume of a 48-percent aqueous solution of hydrofluoric acid + 1 part by volume of a 99-percent aqueous solution of acetic acid + 2 parts by volume of an 85-percent solution of ortho-phosphoric acid + 100 parts by volume of water;
- Solution B: 0.1 molar N-n-butylpyridinium chloride; and
- Solution C: 1 molar NH_3F_2.



The **Majority-Carrier Concentration** of a specimen of n^{+}-doped InP deposited on n-doped InP deposited on n^{++}-doped InP substrate was determined by electrochemical profiling in the UNIEL solution.

Electrochemical profiling can contribute to characterization and thus to the development of layered InP- and GaAs-based semiconductor device structures for photovoltaic cells. Current-vs.-voltage, capacitance-vs.-voltage, and conductance-vs.-voltage characteristics obtained by electrochemical profiling can be used to determine surface and bulk semiconductor properties like diffusion length, lifetime of minority charge carriers, surface recombination velocity, and concentration of majority charge carriers at any depth (see figure).

Prior to the development of UNIEL, six other solutions had been used for chemical profiling solutions of III–V semiconductors. None of the previously developed solutions had been found to be useful on all III–V semiconductor compounds, and neither has UNIEL. However, of all the solutions, UNIEL appears to be useful on the greatest variety of III–V compounds. In particular, it has yielded very good results in tests on n- and p-doped InP and GaAs substrates and homo- and heterostructures made of InP, GaAs, InGaAs, and InGaAsP layers. Preliminary studies have also shown that similar electrolytes based on UNIEL work fairly well for profiling GaP, AlGaP (with high Al content) and InGaSbP epitaxial layers, even with Si and Ge substrates.

This work was done by Maria Faur, Dennis J. Flood, Philip P. Jenkins, and David M. Wilt of **Lewis Research Center** *and Mircea Faur and Manju Goradia of Cleveland State University. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 105*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16509.

Extracting Misalignments of Layers in Microfabricated Devices

Offsets are computed from correlations between digitized images of test lines.

NASA's Jet Propulsion Laboratory, Pasadena, California

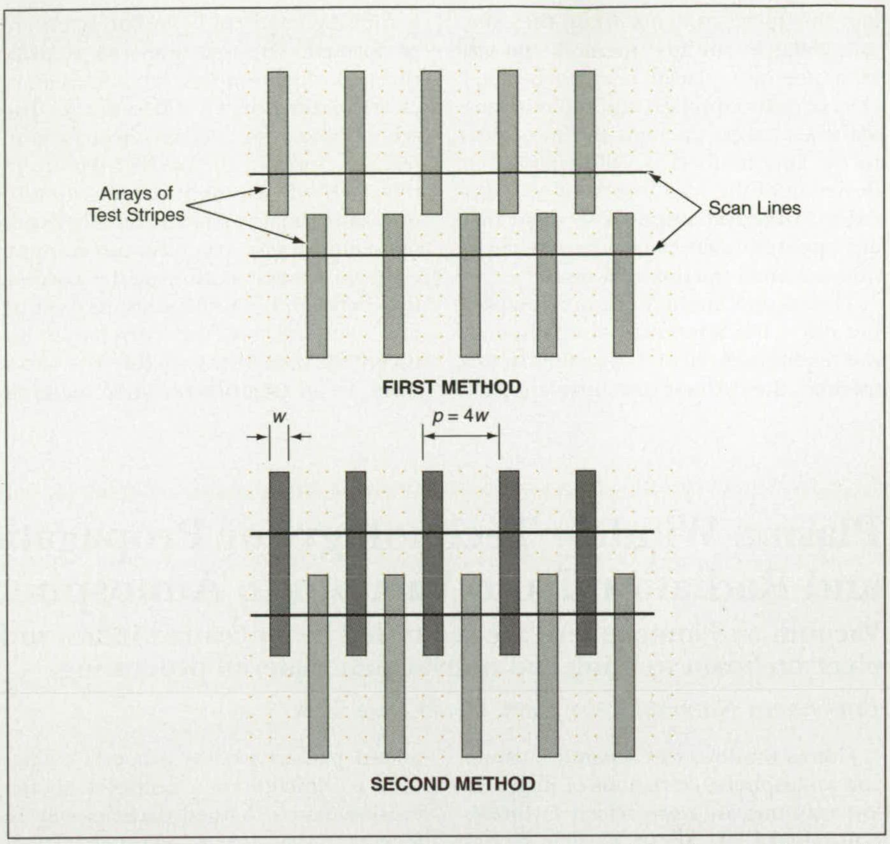
Two closely related methods of optical inspection and computation yield data on misalignments between critical features in different layers of microfabricated devices. Examples of such devices containing features in different layers that are required to be aligned with each other include (1) magnetic-memory devices containing magnetic and nonmagnetic metal lines and grooves in garnet substrates, (2) integrated electronic circuits containing variously patterned metal, semiconductor, and dielectric materials, and (3) micromechanical devices. Before the development of the present methods, misalignments were determined in manual/visual procedures, in which technicians took readings from vernier or wedge test structures.

The present methods also involve the use of test structures, but most of the work of taking the readings and processing the data is automated. The test structures comprise arrays of parallel stripes

of width w and pitch $p = 4w$ (see figure). These arrays are fabricated as integral parts of the layers to be inspected. Nominally, in a given test structure, the arrays in two layers of interest are parallel to each other, with the long axes of the stripes perpendicular to the coordinate axis along which misalignment is to be measured (hereafter called "the axis of interest," for short).

During inspection, a video camera is focused on the device through a high-power microscope to capture an image of the arrays of stripes. The image is digitized, and the resulting data are processed on a personal computer. The processing includes three major tasks, the first of which is a "line scan," in which digitized image intensities are taken as functions of position (with a resolution of 1 pixel) along two lines that are nominally parallel to the axis of interest. The second major task is to compute correlations between the line scans. The third major task is to determine the misalignment distance from the locations of the peaks of the correlation function.

The practices described thus far in general terms are common to both methods. The methods differ in the locations of test structures and line scans and in the associated details of comput-



Two Arrays of Stripes are built into two layers that are to be inspected for alignment. The two different arrangements of arrays and scan lines are associated with somewhat different computational procedures for extracting misalignment distances from correlations.

ing the misalignments from the line-scan data. In the first method, the test structures are placed near each other (but not overlapping), and separate line scans are taken through the two structures. This method is valid only when deviation of the scan line from orthogonality to the test stripes is so small that any apparent shift caused by this deviation is a small fraction of a pixel.

The second method is more complex but offers the advantage of eliminating the requirement of orthogonality. In this method, the two test structures are partly interdigitated, and two line scans are performed. The first line scan is taken through whichever test structure is more clearly defined in the video image. The second line scan is taken through both test structures in the overlap region. In this method, the shift associated with nonorthogonality and the misalignment between the test structures are computed from a combination of the correlation between both line scans of the first test structure and the correlation between the line scans of the two structures. In an experiment, these methods yielded data on misalignments between grooves in a garnet substrate and metal stripes (in another layer) with an error less than half of the 0.5-μm fabrication tolerance of the specimen.

This work was done by Udo Lieneweg of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category,* ***or circle no. 106*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-20016*

Plasma Window Technology for Propagating Particle Beams and Radiation from Vacuum to Atmosphere

Vacuum and atmosphere are separated by a plasma window to facilitate nonvacuum electron-beam welding and nonvacuum material processing.

Brookhaven National Laboratory, Upton, New York

Plasma windows can separate vacuum and atmosphere, or regions of high and low vacuums, in a way which facilitates transmission of various particle beams and/or radiation from low- to high-pressure regions. In a prototype device, a stabilized plasma arc was properly configured to function as a nonsolid plasma window. Since charged particles can be focused by these arcs, focusing of such beams is a secondary function of this device.

Charged particle beams (ions, electrons) and intense x-rays are used in many applications. These beams must be generated in a high vacuum. However, in most applications (like electron-beam welding and material modification by

ion implantation, dry etching, and microfabrication), it is desirable to utilize these beams at atmospheric pressure, since vacuum operation greatly reduces production rates and limits workpiece size. Also, it is desirable to raise the pressure at which electron-beam melting for manufacturing alloys is performed to facilitate manufacturing of superalloys from scrap recovery. This plasma window can facilitate nonvacuum ion material modification, manufacturing of superalloys, and high-quality nonvacuum electron-beam welding.

In vacuum systems that are used in various industrial devices, and in space vehicles, vacuum-atmosphere separation is accomplished with solid walls and windows. In the plasma window, confined ionized gas accomplishes this separation.

Three effects can enable a plasma to provide for a rather effective separation between vacuum and atmosphere, as well as between vacua regions, and even act as a pump:

1) Gas pressure effect: Pressure P (the product of density N, temperature T, and the universal gas constant R) is described by the equation P=NRT. In the plasma window T=12,000 °K compared to room temperature of 300 °K. Therefore, the plasma window matches atmospheric pressure with only $\frac{1}{40}$ of its density.

2) Viscosity effect: Viscosity (friction, resistance to flow) of a gas increases with temperature. Consequently gas flow through a hot plasma-filled channel is substantially reduced compared to a room-temperature gas-filled channel.

3) Pumping effect: Gas atoms and molecules are ionized by plasma electrons and are trapped by the fields confining the plasma window. Experimentally, these effects contributed to a factor of 228.6 pressure reduction over differential pumping. (Details of the theory and the experiments can be found in A. Hershcovitch, *Journal of Applied Physics,* **78** [9], 5283 [1995].)

Plasmas act as lenses on charged particle beams in general. The currents in this plasma window generate azimuthal magnetic fields which deflect (focus) the particles radially inward (via the Lorentz force). This plasma lens is stronger than the general case where the beam-generated field focuses. More details can be found in the paper cited above.

Curiously, the plasma window functions in a way which very superficially resembles the force field in the Star Trek TV series. For example, there is an area on the Enterprise (the Shuttle Bay) from which shuttle crafts leave for flights into space. At the edge of that area there is a force field (with a bluish glow at its perimeter) which separates the atmosphere (air) on the Enterprise and the vacuum (space) outside. Similarly, in the plasma window, a plasma (which is an ionized gas confined by electric and magnetic fields) separates air from a vacuum by preventing the air from rushing into the vacuum. A variety of gases can be used to operate this window. When argon is used, the window color is blue, similar to that shown in Star Trek.

Electron-beam welding has many well-known advantages over other techniques: a high depth-to-width ratio of the welds, very high energy efficiency (since electrical energy is converted directly into beam-output energy), low distortion, and the ability to weld reasonably square butt joints without filler-metal addition. Principal components of an electron-beam welding column assembly are: an electron gun, magnetic focusing lens, deflection coils, and the workpiece. The electron gun must be held at a pressure below 10^{-4} Torr. In present-day technology, the vast majority of electron-beam welding, with very few exceptions, is done in vacuum. Some of the shortcomings of vacuum welding are low production rates due to required pumping time, and limits the vacuum system sets on the size of assemblies to be welded. Thus the major advantages of nonvacuum welding are the elimination of the vacuum-chamber evacuation time and limits on the weldment size.

However, since the electron gun must be kept in vacuum, in the few nonvacuum electron-beam welding machines in exis-

tence, the beam itself is generated in high vacuums. Then it is projected through several orifices separating a series of differentially pumped chambers, before emerging into the work environment that is at atmospheric pressure. This causes large dispersion in the electron beam, which practically nullifies all the advantages of electron-beam welding.

Material modifications by ion implantation, dry etching, and microfabrication are widely used technologies, all of which are performed in vacuum, since ion beams at energies used in these applications are completely attenuated by foils and by long differentially pumped sections. Therefore, no attempts at applying these technologies in atmosphere were ever made. Electron-beam melting for manufacturing alloys is performed at a pressure of about 10^{-2} Torr. A major drawback of operating at this pressure range is the loss of elements with low vapor pressure. Consequently, it is desirable to raise the operating pressure to as high a level as possible, preferably reaching operation in atmosphere.

To rectify the shortcomings of present-day vacuum-atmosphere interfaces, orifices and differentially pumped chambers can be replaced by a short high-pressure arc—a plasma window—that interfaces between the vacuum chamber and atmosphere and has the additional advantage of focusing charged particle beams.

For transmission of high-energy synchrotron radiation, conventional beryllium windows can be replaced with plasma windows to avoid many of the problems associated with solid windows. Plasma windows offer many advantages over presently used beryllium windows, since the interaction of high-energy photons with plasmas that form these windows is negligible, *i.e.*, the radiation passes through unaffected. Additionally, a plasma window cannot be damaged by radiation.

This work was done by Ady Hershcovitch at the Department of Energy's **Brookhaven National Laboratory**, *Upton, New York. Inquiries concerning rights for the commercial use of this invention should be addressed to David Langiulli, Office of Technology Transfer, Building 902C, Brookhaven National Laboratory, Upton, NY 11973; E-mail: DAVID@BNL.GOV.*

Fabrication of Arrays of Large Step-Free Regions on Si(100)

Atomically flat silicon surfaces can be created with a new process.

Cornell University, Ithaca, New York

When a silicon wafer is cut from an ingot, it is essentially impossible to align the cut perfectly with the crystal structure. Therefore the surface contour of the wafer will be a flat plane on which terraces consisting of additional atomic layers will be scattered. An atomic step will be found on the surface where each additional layer is encountered. At elevated temperatures, these atomic steps will migrate, but they cannot be eliminated. At the current level of device technology, the effects of steps on the wafer surface can be largely ignored. In future generations of integrated circuits, however, the sizes of these steps will become comparable to some device feature sizes and will affect circuit performance and yields.

The method of the invention is to create a grid pattern on the surface of the wafer, dividing it into an array of squares separated by ridges. In the demonstration project, the squares ranged in dimension from 2 to 50 microns on each side, and the ridges were approximately 0.5 micron high and 1 micron wide. The wafer is then annealed at a temperature of between 1020 and 1150 °C. At the annealing temperature, the atomic steps migrate to and join with the ridges, leaving the square surface areas atomically flat. The dimensions and shapes of the step-free regions could be designed to accommodate particular device arrays.

This invention eliminates one of the major limitations in the further miniaturization of microelectronic devices through the commitment of only a small percentage of the area of the wafer (≤10 percent) to the grid pattern. It is able to accomplish this through technology that is currently available and easily implemented. Circuits built on step-free surfaces can be designed with smaller dimensions and utilize thinner semiconductor and insulation layers to increase performance and decrease power consumption.

Work continues to determine the maximum dimensions of the flattened areas and the optimum combination of annealing time and temperature. The processing time required depends on the initial quality of the surface. Development of alternative processes is under way. One alternative process uses trenches, rather than ridges, to separate the flattened areas, and deposition rather than evaporation. It will have the advantage of achieving these results at lower temperatures.

By providing a silicon substrate that is perfectly flat, this invention gives integrated circuit manufacturers the ideal sur-

face on which to build devices. The inventive method does not require exotic equipment, unfamiliar processes, or high precision. The flattened areas on the wafer can be made large enough to accommodate an entire circuit. The remnants of the ridge regions involve only small slopes and hence do not present problems in interconnects. Circuit sizes can be decreased, and performance and production yields can be expected to increase. This process can be implemented in stages. After a processing cycle, wafers that do not meet specifications may be recycled until the desired results are achieved.

This work was done by Jack Blakeley, So Tanaka, C.C. Umbach, and Ruud Tromp at **Cornell University**. *For more information, call Robert F. Schleelein, Technology Marketing and Licensing Specialist, Cornell Research Foundation Inc., 20 Thornwood Drive, Suite 105, Ithaca, NY 14850; (607) 257-1081; fax (607) 257-1015; E-mail: rfs4@cornell. edu; http://www.research.cornell.edu/crf.*

Reflective Coating System for High-Temperature Vacuum Use

This system retains its reflectivity after heating to 500 °C.

Lewis Research Center, Cleveland, Ohio

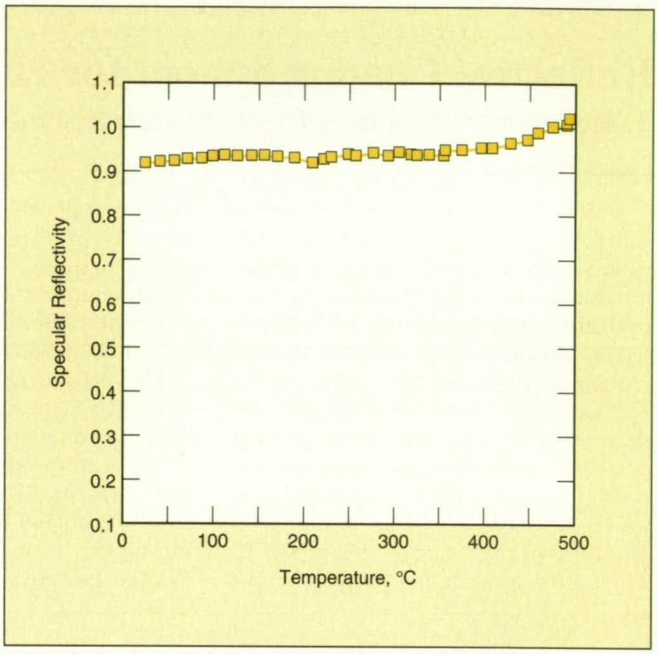
A substrate of nickel coated with a thin layer of silver and further coated with a thin protective layer of silicon dioxide has been found to constitute an optically reflective substrate/coating system that is suitable for use at high temperature in vacuum. This system was developed originally for use on space solar dynamic and solar thermal power systems and, in particular, on secondary solar-radiation concentrators, which are expected to operate at temperatures in the range of 400 to 800 °C. This substrate/coating system might also be applicable to hot optical components of terrestrial solar electric-power systems, solar-powered waste-water-treatment systems, solar-powered fiber-optic illumination systems, and laboratory optical instruments.

The predecessors to this substrate/coating system include a pure silver substrate diamond-turned to a mirror finish, a pure copper substrate coated with silver, and a single-crystal sapphire substrate coated with silver. After heating to 450 °C, the pure silver substrate exhibited severe grain-boundary growth, which rendered the surface diffuse. After heating to 420 °C, the copper-substrate/silver system exhibited diffusion of silver into the copper, rendering the surface layer silver poor. The sapphire/silver system exhibited excellent reflectivity characteristics when heated to 530 °C, but this system was deemed impractical because sapphire would be difficult to form into the shape of a secondary concentrator.

Silver has long been the reflective coating material of choice for use at room temperature. The present SiO_2-

on-Ag-on-Ni substrate/coating system retains its reflectivity at high temperature, at least partly because with nickel as the substrate, little or no silver diffuses into the substrate. Moreover, the nickel substrate can readily be machined to a desired shape and can be either metallurgically polished or diamond-turned to a mirror finish.

Initial samples of this substrate/coating system were fabricated by polishing nickel substrates to a mirror finish, followed by electron-beam evaporation (alternatively, sputtering could be used) to deposit silver to a thickness of 1,000 Å,



A **Sample Retained High Specular Reflectivity** during heating over a wide temperature range.

followed by deposition of SiO_2 to a thickness of 1,000 Å. During a test of the first sample, the specular reflectivity was found not to change appreciably as the sample was heated from room temperature to almost 500 °C (see figure). Microscopic examination of a sample that had been heated to 798.5 °C revealed many small grains — too small to affect the reflectivity.

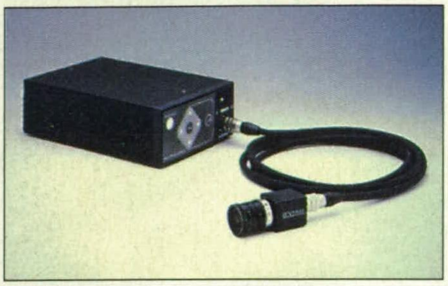
The smallness of the grains may be a fortuitous result of the thinness of the silver layer. It has been conjectured that the sizes of the grains might increase with the thickness of the silver. Thus, there might be an upper limit to the desired silver thickness, beyond which the specular reflectivity could be degraded by the formation of larger grains. Apparently, the upper limit is greater than the 1,000 Å of the initial samples. Optionally, one might select greater thicknesses of silver to promote the formation of larger grains in order to obtain diffusely reflective high-temperature coating/substrate combinations for use in optical components (*e.g.*, integrating spheres) for capturing and diffusing light at high temperatures.

This work was done by Donald A. Jaworske of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 107*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16411.

NEW PRODUCTS

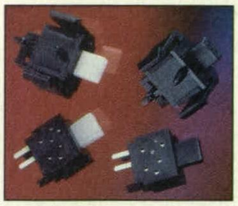
PRODUCT OF THE MONTH



Small Color CCD Camera Module

New from Sony Business and Professional Group, Park Ridge, NJ, is the XC-333 quarter-inch color CCD micro-camera module. The company says that with its square shape and ruggedized compact design, the camera is suited for integration into many industrial applications. Incorporating a digital signal processing (DSP) chip for control, the camera may be adjusted externally via an RS-232 link. The XC-333 offers resolution of 470 TV lines (768 × 494 pixels) and has automatic gain control. The head unit measures 22 × 22 × 30 mm, and is controlled from an attached unit that measures 50 × 110 × 160 mm. The camera has a miniature Sony NF lens mount, and a C-mount lens adapter is also available.

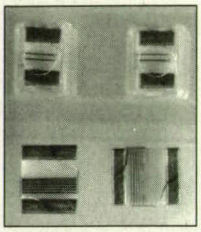
For More Information Circle No. 796



AC Line-Interrupt Switches

Cherry Electrical Products, Waukegan, IL, introduces the CS Series of pushbutton switches suitable for PC board mounting. The series features a long 5-mm stroke with 4 mm of overtravel, providing a high degree of mechanical margin for both mounting and sensing positions, the company says. The switch is available in either snap-in panel mounting or PC board mounting styles; the latter includes insertion-molded terminals for automatic soldering environments. Standard and light operating force versions are available.

For More Information Circle No. 797



SMT Miniature Chip Inductors

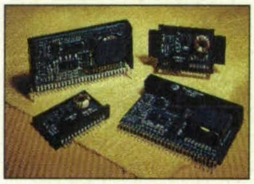
Vanguard Electronics Co., Gardena, CA, is offering the V0603/V0805/V1008 series surface-mount technology miniature ceramic chip inductors. The devices, which the company calls the smallest fixed inductors available, are wire-wound on a ceramic body. Available in 0603, 0805, and 1008 footprints, the inductors are available in 189 configurations to suit a broad range of applications, ranging from pick-and-place assembly to communications and broadcast. Tolerances range from 20 percent to 2 percent, and a choice of solder or gold terminations is available.

For More Information Circle No. 798

Thermal Analysis for Electronics

Dynamic Soft Analysis Inc. Pittsburgh, PA, releases the BETAsoft-EasyBoard to perform fully three-dimensional fluid modelling, conduction, convection, and radiation analysis of electronic boards. The company calls the device the only Windows-based board-level thermal analysis program available. It can analyze boards at ground elevation with up to 300 components on each side. A pre-established library of 2500 components simplifies input requirements. Interfaces to most ECAD placement files are provided for seamless integration in the design. The algorithm enables fast analysis on PCs, which can predict results within 3 °C for 30 °C temperature rises.

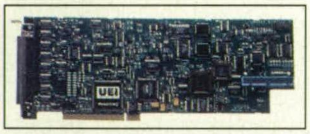
For More Information Circle No. 801



Bus Surface-Mount Power Modules

Power Trends Inc., Warrenville, IL, has made four new series of 12-V and 24-V bus power modules available. The PT6620 (12-V input) and PT6650 (24-V) can supply output currents of 7 and 5 A respectively; the PT7720 (12-V input) and PT7750 (24-V) can supply output currents of up to 20 A. Power Trends says all four feature output inhibit function, remote sense, and over-temperature shutdown, and are available in surface-mount configurations. In quantities of 1000, prices are: PT6620 and PT6650 $17.50 each, PT7720 $33.00, and PT7750 $36.50.

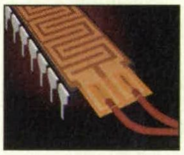
For More Information Circle No. 800



PCI-Based A/D Board

United Electronic Industries (UEI), Watertown, MA, announces a PCI-based A/D board based on PowerDAQ technology. The PD-MF-330/12 comprises four models with a processor-based Motorola 56301 PCI DSP interface. The boards allow the offloading of the host CPU data acquisition functions to the on-board DSP. The board comprises four subsystems: analog input, analog output, digital I/O, and counter/timers. The 330-kHz 16-channel board sells for $895, and the 64-channel version for $1395.

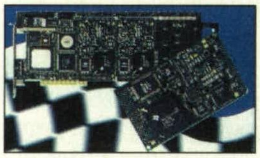
For More Information Circle No. 799



Miniature Component Heating Elements

Minco Products Inc., Minneapolis, MN, offers its Thermofoil™ heaters in sizes as small as 0.25 × 0.25 in. (6.4 × 6.4 mm) for electronic components. The polyimide heaters mount directly to component bodies with self-stick adhesive, or may be clamped underneath. They operate from -200 to 200 °C (-328 to 392 °F) with power ratings to 50 W per square inch. Twelve-inch leadwires are standard for electrical termination; solder pads or flex circuits are available as custom options. Applications include temperature stabilization of crystal oscillators, thermal stress testing of integrated circuits, and simulation of heat-emitting components.

For More Information Circle No. 802



Digital Radio Receiver Module

Spectrum Signal Processing, Burnaby, BC, Canada, offers the TIM-SDR single-channel digital radio receiver module and software demodulation libraries. The receiver combines a 70-MHz A/D converter, a Harris HSP50016 narrow-band digital down-converter, a 60-MHz 'C44 digital signal processor, and a 250-kHz D/A converter on a single-width mezzanine TIM-40™ module. The company says the modular 'C-4x-based product allows engineers to create a solution that is scaled to meet the exact processing requirements of their application.

For More Information Circle No. 806

Electronics TECH BRIEFS LITERATURE

FREE EMI/RFI TUTORIAL

A free tutorial covering EMI/RFI problems in electronic enclosures and their solutions is available from Equipto Electronics. It covers FCC, military specifications, and EMP, TEMPEST concerns. Shock and vibration solutions, including seismic, are included. Company representatives will present the tutorial along with product samples. Equipto Electronics Corp., 351 Woodlawn Avenue, Aurora, IL 60506-9988; phone 800-204-RACK; fax (630) 897-5314; web site: www.equiptoelec.com.

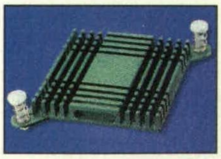
Equipto Electronics Corp.

For More Information Circle No. 490

Flat-Panel Plasma Display

Fujitsu Microelectronics, San Jose, CA, is offering a new ImageSite™ 42 flat-panel display. The company says that the new model has twice the brightness and nearly six times the contrast of the previous model. Fan speed has been lowered, reducing noise. Designed for the "digital convergence" of computers and television, the ImageSite 42 seamlessly displays graphical information from any source, including PC, Macintosh, the Internet, LANs, CD-ROM, and others. The display has a viewing angle of 160 degrees both horizontally and vertically.

For More Information Circle No. 804



Heat Sinks for BGA ICs

Aavid Thermal Products Inc., Concord, NH, announces a new heat sink designed for use in integrated circuits packaged in a ball grid array (BGA). The new heat sink, available for 27-×-27-mm and 35-×-35-mm BGA packages, is recommended for use with applications utilizing Intel's Pentium II® accelerated graphics port (AGP), peripheral connection interface (PCI), LX, and DX chip sets. The pin spacing fits the standard mounting holes found on 60 percent of Pentium II motherboards. The BGA heat sinks provide a thermal resistance of 13.3 °C/W and 8.0 °C/W at 200 f/m for the 27-mm and the 35-mm packages respectively.

For More Information Circle No. 805

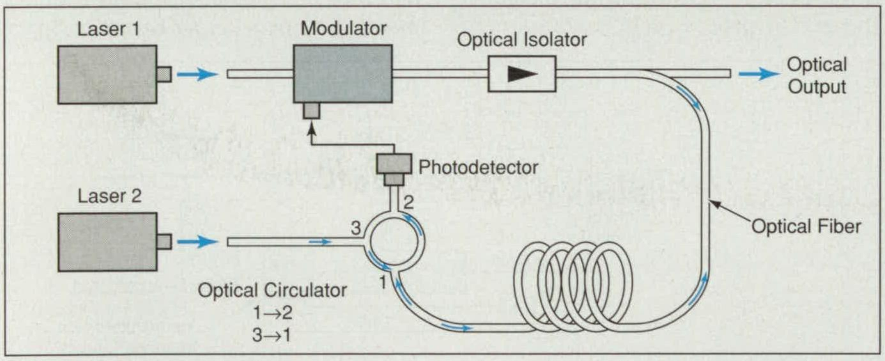
Optoelectronic Oscillators Based on Brillouin Scattering

Electronic amplifiers and filters are not needed.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved type of optoelectronic oscillator is based on Brillouin amplification. An oscillator of this type converts light energy into an electro-optical oscillation, typically at a frequency of several gigahertz. It offers several advantages over other electro-optical and over all-electronic oscillators:

- There is no need for a relatively bulky, expensive, power-consuming electronic microwave amplifier.
- Without the flicker noise associated with an electronic microwave amplifier, it should be possible to obtain lower oscillator phase noise.
- The narrow gain bandwidth of Brillouin amplification provides band-pass filtering, making it unnecessary to use a relatively bulky electrical band-pass filter; this feature contributes potential for miniaturization and integration.
- The frequency of oscillation can be tuned over a broad range by changing the frequency of one or two pump laser(s).
- A phase modulator can be used in place of a more-expensive and higher-loss amplitude modulator. Because no bias is necessary for a phase modulator, the bias drift associated with an amplitude modulator is eliminated.



This **Simplified Schematic Diagram** represents one of a number of developmental optoelectronic oscillators based on Brillouin amplification.

The device is based on Brillouin selective sideband amplification (BSSA), the basic principles of which were described in the two preceding articles, "Exploiting Brillouin Scattering in Analog Signal Processing" (NPO-20091) and "More Uses for Brillouin Amplification" (NPO-20092). To recapitulate: Brillouin scattering is the scattering of photons by phonons and is the most sensitive nonlinear optical effect in optical fibers. At a laser-signal power level above a threshold specific to a given optical fiber, SBS generates an acoustic grating via the electrostrictive effect, and the grating gives rise to back-scattering of the forward-propagating optical signal.

Suppose that one laser beam, regarded as a pump signal, is coupled into one end of a long optical fiber. Suppose that another, weaker laser beam, regarded as a carrier signal, is modulated with a radio-frequency signal and coupled into the other end of the long optical fiber. Suppose, further, that the pump or the carrier laser is adjusted so that the carrier frequency is lower than the pump frequency by such an amount as to place the lower sideband of the modulated carrier signal at the SBS peak of the pump signal. As a result, the lower sideband joins the back-scattered pump signal and becomes amplified by the nonlinear SBS effect. The amount of amplification diminishes gradually with departure of the lower sideband frequency from the SBS peak. The carrier and upper sideband are sufficiently distant in frequency from the SBS peak that they are not amplified.

The figure illustrates a basic oscillator of the present type, which exploits Brillouin amplification in an optoelectronic feedback loop. Continuous-wave laser 1 is the carrier laser. The carrier laser beam, at frequency ν_1, passes through an electro-optical modulator and an optical isolator into one end of a long optical fiber that serves as a delay line and as the amplifying medium. Continuous-wave laser 2 is the pump laser. The pump laser beam, at frequency ν_2, is introduced through an optical circulator or optical coupler at the other end of the optical fiber. At the end where the pump beam is introduced, a photodetector detects the modulated carrier beam that has propagated along the fiber to this end. The electrical output of the photodetector is applied to the modulator.

Initially, the signal applied to the modulator consists of noise, and thus the carrier signal is modulated initially by noise. However, the only part of the optical signal spectrum that becomes amplified is the component at the Brillouin-scattering frequency; this component gives rise to a beat signal in the photodetector output. The beat signal then drives the modulator to produce a stronger sideband at the beat frequency below the carrier frequency. Thus, through positive feedback, the beat signal (which constitutes the desired oscillation) becomes stronger until the gain saturates. The frequency of oscillation is given by

$$f_{osc} = \nu_1 - \nu_2 + \nu_{BS},$$

where ν_{BS} is the Stokes frequency shift of Brillouin scattering.

A prototype oscillator was constructed, using an optical fiber 12.8 km long with a Stokes frequency shift of 12.8 GHz at a laser wavelength of 1,320 nm. The beam from a single yttrium aluminum garnet (YAG) laser with an output power of 70 mW was split to generate both the pump and carrier signals at this wavelength ($\nu_1 = \nu_2$ in this case). This apparatus was found to generate an electro-optical oscillation with a power of about −11 dBm at the output of the photodetector. Because the Brillouin gain bandwidth was 10 MHz but the mode spacing associated with the 12.8-km fiber length was <10 kHz, mode hopping was observed. Further development effort would be necessary to eliminate mode hopping.

This work was done by X. Steve Yao of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category,* ***or circle no. 172*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
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Refer to NPO-20097, volume and number of this NASA Tech Briefs *issue, and the page number.*

Automated Vision System Inspects a Large Surface

Inspection data can be acquired quickly and readily, compared with data from previous inspections.

John F. Kennedy Space Center, Florida

The figure schematically illustrates an automated electronic vision system that operates in conjunction with a scanning robot to inspect a large surface for damage. In the original application for which the system was developed, the surface comprises the panels of the space shuttle thermal radiators, with a total area of more than 1,200 ft^2 (>111 m^2). Typically, the whole area contains between zero and five damage sites, though occasionally it contains hundreds of damage sites, along with hundreds of nondamage sites that may look like damage sites at first glance. Heretofore, the surface was inspected by technicians using flashlights and magnifying glasses in a tedious, slow, labor-intensive process, and the inspection data were recorded manually in a form not readily accessible for review and analysis. The automated vision system performs the inspection much faster and stores results in a data base that is readily accessible for review and analysis.

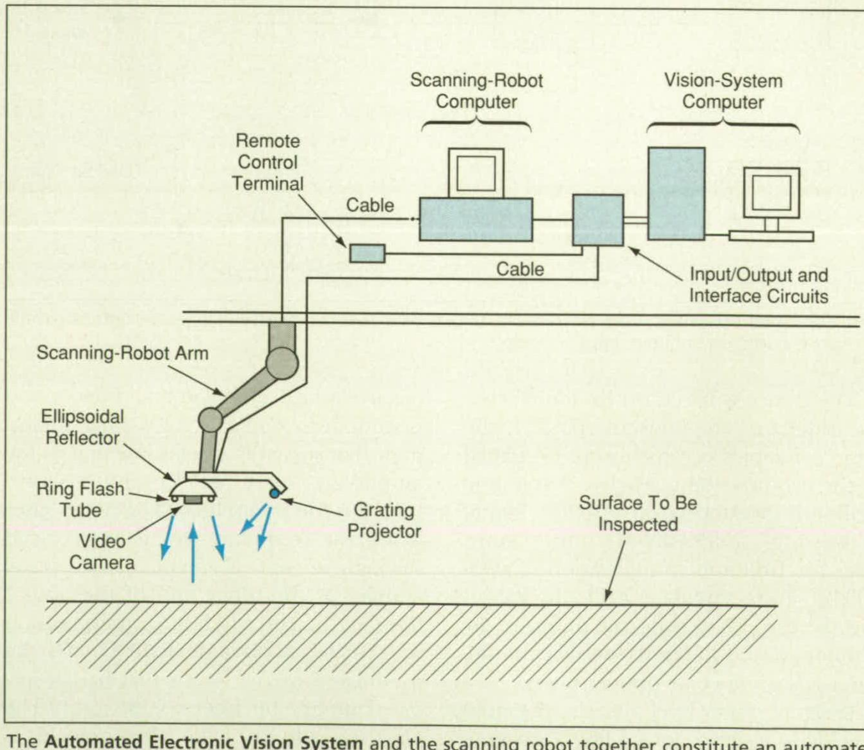
The system includes a high-resolution video camera mounted on the scanning robot arm, along with two stroboscopic illuminators, about 2 ft (0.6 m) away from the surface to be inspected. The camera and illuminators operate under control by a computer, and the video output is digitized and sent to the computer. The system scans the surface in a continuous motion, viewing a square area about 5 in. (13 cm) on a side. Data are taken when the stroboscopic illuminators "freeze" the motion at intervals of 4 in. (10 cm) along the surface.

The two illuminators are used to reveal different kinds of damage. One illuminator comprises a ring flash lamp that encircles the camera, plus an ellipsoidal reflector behind the camera and flash lamp. The camera and flash lamp lie in one focal plane of the ellipsoid, and the surface to be inspected lies midway between the two focal planes of the ellipsoid. Thus, the surface is illuminated diffusely and nearly uniformly and light reflected from the surface fills the camera lens nearly uniformly over the entire field of view. This optical arrangement provides a bright field illumination system that highlights small damage sites over an extended inspection area. This illuminator is used along with a component of image-data-analysis software to find such microscopic damage as punctures and scratches. The software implements a number of steps in which image background clutter is filtered out and each damage or nondamage site is characterized in terms of a list of specific features that include location, size, and shape. The lists of features for all sites are stored in the data base and the rest of the image data are discarded.

The other illuminator incorporates slide-projector optics and is located on a boom about 2 ft (0.6 m) to one side of the camera. This illuminator projects a grating (that is, a grid pattern in white light, not to be confused with a diffraction grating) onto the surface to be inspected. The resulting image of the grid is processed by a component of image-data-analysis software to find such macroscopic damage as large dents and tape delaminations. The software first processes the image of the grating to obtain the digital equivalent of a depth map of the surface. The depth-map data are then processed in a manner similar to that of the diffuse-illumination-image data to filter out background clutter, characterize each damage or nondamage site in terms of a list of specific features, and store the list of features in the data base.

The problem of identifying relatively few damage sites is solved relatively easily by use of this system. An initial inspection generates a nondamage portion of the data base. The computer can then compare feature data acquired in subsequent inspections with this portion of the data base to find changes indicative of damage that has occurred in the interim.

This work was done by Edward D. Huber and Rick A. Williams of Lockheed Martin Missiles & Space Co. for **Kennedy Space**



The **Automated Electronic Vision System** and the scanning robot together constitute an automated inspection system that can quickly find a few damage sites on a large surface.

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Title to this invention, covered by U.S. Patent No. 5,608,215 has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to

Edward D. Huber
Lockheed Martin Missiles & Space Co., Inc.
Dept. H1-52, Bldg. 202
Advanced Technology Center
3251 Hanover St.
Palo Alto, CA 94304
(650) 424-3308

Refer to KSC-11726, volume and number of this NASA Tech Briefs *issue, and the page number.*

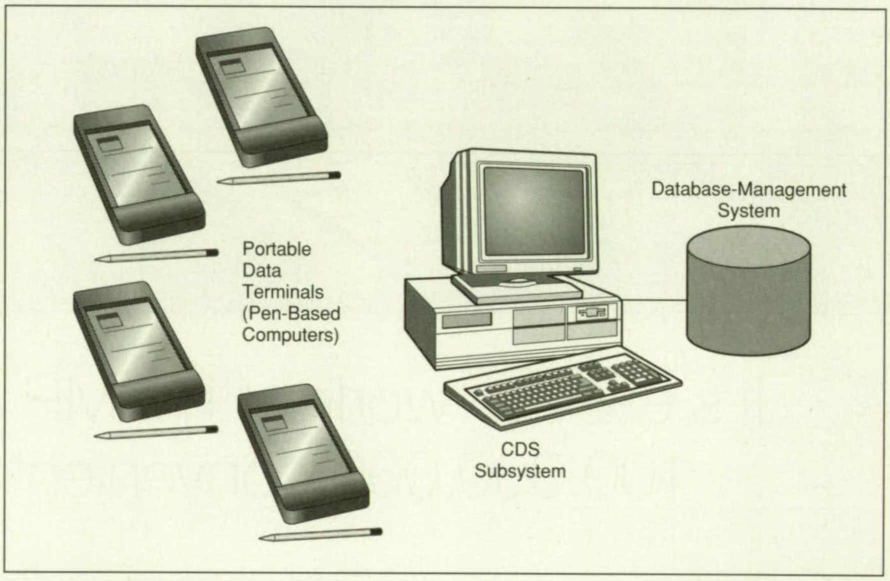
Computer System for Collection of Quality-Assurance Data

Data are recorded on portable pen computers instead of paper forms.

John F. Kennedy Space Center, Florida

The Paperless Procedure System (PPS) is a computer-based, semiautomated electronic system for collection and management of quality-assurance data in a large organization. The original version of PPS was designed for use by Kennedy Space Center personnel engaged in inspection tasks during test and assembly procedures that are part of preparing the space shuttle and its payloads for flight. The PPS was also designed to be adaptable to nonaerospace commercial applications.

The PPS serves a need to increase productivity and improve the availability of inspection data while maintaining the safety and quality of service in the face of reductions in the number of workers. Heretofore, data from inspections have been written on paper forms, from which the data are subsequently scanned into an archival computer memory in a central database-management system. In the PPS, on the other hand, there is no need for paper forms and the attendant manual processing steps; instead, inspection data are recorded on compact, portable data terminals (pen-based computers) and thereafter processed automatically.



Portable Data Terminals take the place of paper inspection forms. These terminals communicate with the CDS subsystem.

The portable data terminals communicate with a central database server (CDS) subsystem, which includes computer hardware and software performing the functions of a network host and database server (see figure). The PPS makes electronic forms, work-flow-management software tools, and network communication resources accessible to mobile personnel. The most innovative components of the PPS software are the Intelligent Forms Converter (IFC), Data Format Converter (DFC), Inspector's Smart Stamp (ISS™) modules.

The IFC module automates the development of electronic (as distinguished from paper) representations of test and assembly procedures. Unlike in typical other pen-based computer systems, there is no need for a software engineer to reprogram the system and its electronic forms each time the requirements for test and assembly procedure change. Instead, the IFC module accepts, as input, an electronic representation of a test and assembly procedure prepared in a commercial word-processing program. The IFC module then automatically converts the input into the proper electronic format for execution on a pen-based computer.

The DFC module satisfies requirements for preserving all test data, images of inspectors' stamps, notes, deviations, and constraints recorded during a test and assembly procedure that has recently been executed. The DFC converts this recorded information into a final electronic document in a prescribed format. This electronic document is designated an official record of the procedure and is not permitted to be altered subsequently.

The ISS™ module provides an electronic means of authentication analogous to an inspector's ink stamp. The ISS™ module is executed with the help of silicon-based memory devices that store the information necessary for electronic generation of stamp images similar to the ink versions. An inspector causes a stamp image to be generated by touching one of these memory devices to a probe on a portable data terminal.

This work was done by Eric A. Adolphe and Mark Sullivan of Optimus Corp. and Patrick Xantus of Sentel Corp. for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 147*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Sentel Corp.
225 Reinekers Lane
Suite 500
Alexandria, VA 22314

Refer to KSC-11943, volume and number of this NASA Tech Briefs *issue, and the page number.*

Physical Sciences

Chimera/Unstructured Hybrid Grids for Flow and Heat Transfer

Flow and heat flux in the flow and bounding structure(s) can be computed together.

Lewis Research Center, Cleveland, Ohio

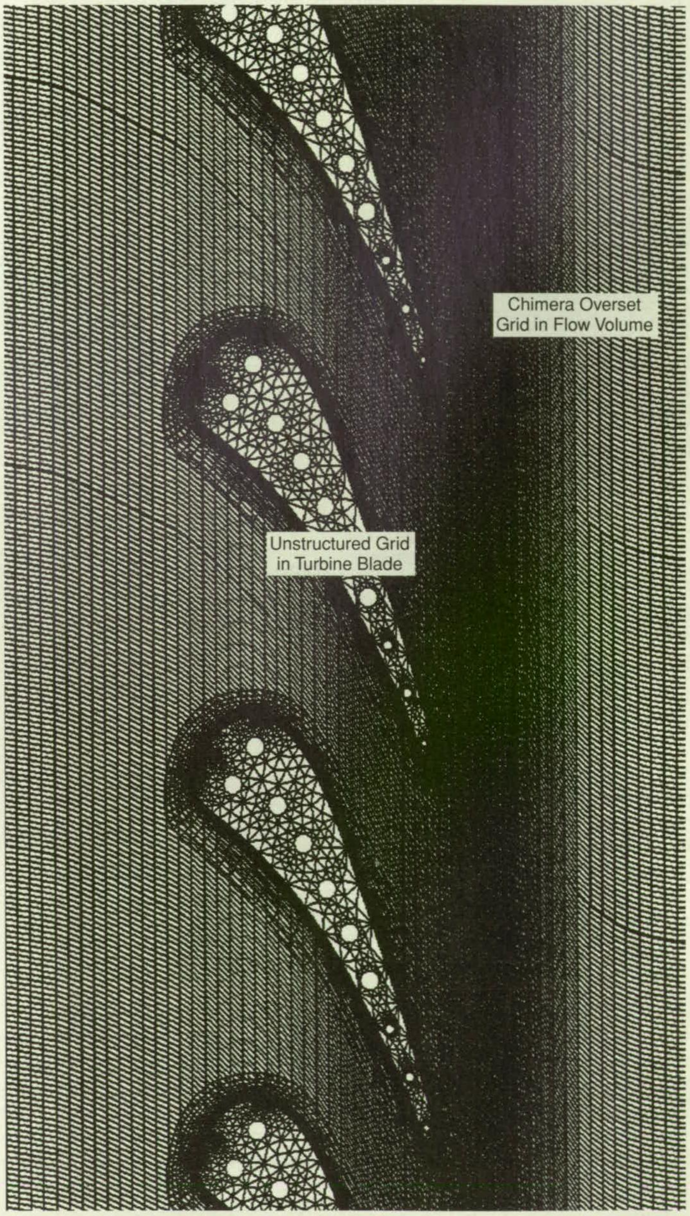
A hybrid-grid scheme has been developed to afford a computationally efficient means for numerically solving equations of both (1) coupled flows of heat and mass in a fluid and (2) conduction of heat in a body or bodies that bound the fluid. The scheme should prove especially beneficial in analyzing aerodynamic, thermal, and structural effects in turbomachinery.

Among grid methods now in use, the chimera-overset-grid method offers the most flexibility and computational efficiency in representing flows bounded by complexly shaped bodies. A chimera grid is a set of overlapped structured grids that are generated independently and fitted to the body or bodies of interest. A chimera overset grid is a chimera grid that includes (1) a major grid generated about a main body element and (2) minor grids superimposed on the major grid to resolve interesting features of the configuration.

The unstructured-grid method facilitates the solution of problems pertaining to solid bodies (e.g., strain problems). However, the unstructured-grid method does not offer computational efficiency for solving flow and heat-transfer problems.

The present hybrid scheme is intended to take advantage of the strengths of the chimera-overset-grid and unstructured-grid methods. The scheme involves the use of a chimera overset grid in the flow volume, coupled to an unstructured grid or grids for modeling conduction of heat in the bounding body or bodies.

Unlike in older grid schemes and associated numerical-solution methods, in the present scheme, one need not assume physically unrealistic prescribed heat fluxes (e.g., zero heat flux in the traditional adiabatic-wall assumption) or constant temperatures at fluid/solid interfaces. Instead, the heat fluxes in the fluid and solid are treated more realistically as unknowns that are coupled to each other; following a conjugate-analysis approach, the temperatures and heat fluxes are required to be continuous across fluid/solid interfaces. In this scheme, one performs a conjugate analysis, wherein the mass flow and the heat fluxes are treated as parts of an integral system, the equations of which can be



A **Chimera/Unstructured Hybrid Grid** enables the computational treatment of a turbine cascade as one integral system, for which the coupled equations of aerodynamic, thermal, and structural effects can be solved together.

efficiently solved together to obtain aerodynamic, thermal, and structural effects.

The scheme has been tested by using it to compute flows about, and distributions of temperature within, a cooled flat plate and a turbine cascade with 10 cooling holes per blade (see figure). The results of these computations are in substantial agreement with results of experiments. In the foregoing computations and in other computations for a simplified drum/disk structure, conduction of heat in solid bodies has been shown to affect surface temperatures in that these temperatures differ from those computed with the adiabatic-wall assumption.

This work was done by Meng-Sing Liou of **Lewis Research Center** *and Kai-Hsiung Kao of the Institute for Computational Fluid Mechanics in Propulsion. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 162*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16431.

Aircraft-Skin-Rivet Thermocouple

This device measures temperature without disturbing airflow.

Lewis Research Center, Cleveland, Ohio

The aircraft-skin-rivet thermocouple is designed for measuring the temperature on the outer surface of an airplane wing under icing conditions. More specifically, its design was motivated by the need to measure the temperature near 32 °F (0 °C) on an aluminum wing skin, with an error of no more than 1 °F (0.6 °C), without disturbing the airflow over the wing.

As its name suggests, the aircraft-skin-rivet thermocouple is a thermocouple embedded in an aircraft-skin rivet, with connections to thermocouple wires routed inside the wing. This design satisfies a requirement for simplicity of installation in the field, without need for access to the interior of the wing (other than for routing and connection of the thermocouple wires). Inasmuch as rivets are used in any event to hold the skin in place, this design satisfies a requirement for compatibility with the skin. Like the other rivets on the wing, the one that holds the thermocouple is made flush with the surface upon installation and therefore does not introduce any surface alteration that would disturb the airflow.

At the time of reporting the information for this article, measurements and calculations to determine the accuracy of the aircraft-skin-rivet thermocouple had not been completed. However, preliminary estimates had been interpreted as signifying that the thermocouple readings would eventually be found to be accurate within less than the design error.

This work was done by David W. Sheldon and Dean R. Miller of **Lewis Research**

Center. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 164*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16397.

Source of Fast Oxygen Atoms for Testing Satellite Materials

A high-flux source of 8-km/s oxygen atoms can be used to evaluate aging of materials in near-Earth outer space.

Physical Sciences Inc., Andover, MA

We have developed an apparatus that generates a pulsed beam of fast oxygen atoms, under Small Business Innovation Research (SBIR) funding by NASA's Jet Propulsion Laboratory, to provide a ground test facility to qualify materials to be used in low Earth orbit (LEO). This development was in response to a number of early space-shuttle observations of material erosion and property change resulting from interaction with the LEO atmosphere, which is predominantly monatomic oxygen. These interactions occur at orbital speeds ≈8 km/s. To our knowledge, ours is the only system that provides a high-flux beam of neutral oxygen atoms with wide-area operating capability at the desired speed of 8 km/s. Sets of materials (2.5-by-2.5-cm samples) have been simultaneously bombarded by 8-km/s oxygen atoms at fluences of up to 6×10^{21} cm^{-2} in our facility.

The hyperthermal-oxygen-atom source is housed in two stainless-steel six-way crosses, including an 8-in. (20-cm) cross source chamber housing a pulsed oxygen-valve/nozzle assembly, connected to a 16-in. (41-cm) cross expansion chamber. A cryopump attached to the large cross maintains a base pressure of 3×10^{-7} torr (4×10^{-5} Pa).

The oxygen atoms are generated in a pulsed laser discharge in pure O_2. A 12-J/pulse CO_2 laser is focused into a conical expansion nozzle, which has been partially filled with O_2 by a pulsed-beam valve. The resulting plasma, ignited at

the throat, expands out the nozzle, dissociating the molecular oxygen in front of it. The nozzle was designed to allow recombination of ions and electrons while the slower kinetics of atom/atom recombination maintains a highly dissociated beam. The result, at 8 km/s, is an approximately 50-μs pulse of highly dissociated oxygen (>80 percent atoms) with less than 1 percent ion content (the beam is charge-neutral).

Fast O-Beam Properties	
Velocity	8 km/s ± 15% (5 to 12 km/s range)
Fluence	~10^{18} O-atoms/pulse, 3 Hz
Composition	>80% oxygen atoms
Size	Expandable to >1,000 cm^2 area
Charge content	<1% ions (controllable by pseudo-Helmholtz coils)
Metastable content	$O(^1D)$ concentration <0.4%
Temperature	T = 300 K
VUV/UV content	One photon per 10^4 O atoms (similar to LEO)

A Summary highlights the properties of the O-Beam.

The speed (5 to 12 km/s) of atoms in the beam is selected by varying the time delay between the pulsing of the O_2 valve and the triggering of the CO_2 laser. The delay determines the mass of O_2 processed by the pulsed discharge; this mass is inversely related to the speed of the atoms in the beam.

The fidelity of the LEO simulation is critical for evaluation of materials, and so considerable effort has been expended in characterizing the beam. The measured beam properties are summarized in the accompanying table. A variety of diagnostics have been developed for use with the system.

Our O-beam facility has been employed on several occasions to pretest materials that were subsequently flown in space experiments. The ground-test data and flight-test data were found to be in substantial agreement. A most recent large ground test was for the SEE (Space Environments and Effects) program on materials for the EOIM-3 (Evaluation of Oxygen Interactions with Materials Experiment–3) flight. We irradiated 84 materials following a careful protocol of pre- and post-test weighing. The Jet Propulsion Laboratory performed subsequent surface analysis. With a few understood exceptions, as before, the ground-test and flight-test results for these materials were found to be in substantial agreement, demonstrating our ability to simulate LEO conditions.

Our facility is used to provide material-evaluation services. To date, we have tested over 2,000 samples for both government and industrial customers. The facility has also been utilized to investigate other phenomena of importance to LEO operations, including contamination cleanup, scattering distributions and accommodation coefficients, shuttle glow, and excitation of emissions from contaminant gasses.

The basic concept of the fast-atomic-oxygen source has been extended to form fast atomic beams of other species; for example, fluorine, chlorine, and nitrogen atoms, for potential applications in the semiconductor industry.

Physical Sciences Inc. designs, builds, and licenses customized versions of our fast-atom source. Such systems are presently operational at the Center for Studies in Research and Technology, in Toulouse, France, and the European Space Research and Technology Center in Noordwijk, the Netherlands. A system has also recently been delivered to NASDA Tsukuba Space Center in Japan.

This work was performed by George Caledonia and Robert Krech of **Physical Sciences Inc.** *under an SBIR contract monitored by* **NASA's Jet Propulsion Laboratory.** *For more information, please call (978) 689-0003 or E-mail to caledonia@psicorp.com. SBIR0003*

Computer Software

Program Counts Lines of Source Code

The Source Lines of Code Count (SLOCC) computer program counts the number of source lines of a computer code, as an aid in the management of software, documentation of code, estimation of cost, and satisfying miscellaneous code-metric needs. SLOCC accommodates the following programming languages: Ada, Pascal, C++, FORTH, Visual Basic, Z80 Assembly, and MIL-1750 Assembly. Depending on the language, SLOCC counts whichever of the following is or are applicable: source-code lines, continuations of source lines, comment lines, side comment lines (comments on the same lines with source code), end lines, blank lines, and lines of such other types as are appropriate to the target language.

One problem often encountered in counting source-code lines is the interpretation of the count. Because of coding styles, a program could be written in such a way that some lines are counted in a manner different from what one might expect. To resolve ambiguities that arise in connection with differing interpretations and counts, SLOCC affords the capability to log all lines of code into a table, wherein each line of code is identified by type.

SLOCC was written in Microsoft Access Basic. SLOCC requires an IBM-PC-compatible computer that runs Microsoft Access v7.0 or higher and that contains at least 16MB of random-access memory. SLOCC has been implemented successfully under Windows 95 and Windows NT 4.0. SLOCC was released to COSMIC in 1997.

This program was written by Michael Neighbors of Sverdrup Technology, Inc., for **Marshall Space Flight Center.** *No further documentation is available.*
MFS-31225

COSMIC, NASA's Software Technology Transfer Center, has an inventory of over 800 software packages that originally were developed by NASA and its contractors for the U.S. space program. These packages have a wide range of applications other than space exploration and are used by industry, academic institutions, and other government agencies.

For further information about software available from COSMIC, or to receive a free diskette catalog, contact COSMIC at:

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Mechanics

Deflection of Circular Membrane Under Differential Pressure

Equations have been derived for a situation not represented in prior texts.

Goddard Space Flight Center, Greenbelt, Maryland

Equations have been derived to fill a gap in previously published standard collections of stress-and-strain formulas: These are equations for deflection of a thin circular membrane that is clamped rigidly around its periphery and subjected to differential pressure. Related equations were described in "Deflection and Stress in Preloaded Square Membrane," (GSC-13367, Vol. 15, No. 9 (September 1991), page 96 and "Deflection and Stress in Preloaded Rectangular Membrane," (GSC-13561), Vol. 18, No. 3 (March 1994), page 100.

As in the cases of the square and rectangular membranes, the derivation of the equations for the circular membrane follows a strain-energy/virtual deflection approach, which is common in stress-and-strain problems of this kind. The displacements of the membrane under load are initially assumed to be of the form

$$w = w_0\left[1-\left(\frac{r}{a}\right)^2\right]^2 \qquad (1)$$

and

$$u = r(a-r)(c_1 + c_2 r) \qquad (2)$$

where r is the radial coordinate, a is the radius of the clamping edge, w is the transverse displacement (that is, the deflection perpendicular to the nominal membrane plane) at radius r, w_0 is the maximum transverse displacement, u is the radial displacement at radius r, and c_1 and c_2 are constants.

The radial and transverse strains are given, respectively, by

$$\varepsilon_r = \frac{du}{dr} + \frac{1}{2}\left(\frac{dw}{dr}\right)^2 \qquad (3)$$

and

$$\varepsilon_t = \frac{u}{r} \qquad (4)$$

The strain energy associated with stretching of the membrane is given by

$$V = \frac{\pi E h}{1-\nu^2}\int_0^a \left(\varepsilon_r^{\,2} + \varepsilon_t^{\,2} + 2\nu\varepsilon_r\varepsilon_t\right) r\,dr \qquad (5)$$

where E is Young's modulus, h is the thickness of the membrane, and ν is Poisson's ratio.

To calculate the deflection of the membrane, one must solve the foregoing equations to find c_1, c_2, and w_0. First, one substitutes the right sides of equations (1) through (4) for the corresponding terms in equation (5). Using the resulting form of equation (5), one finds c_1 and c_2 by imposing the requirements that

$$\frac{\partial V}{\partial c_1} = 0 \qquad (6)$$

and

$$\frac{\partial V}{\partial c_2} = 0 \qquad (7)$$

Next, one imposes the requirement that the change in work done by the differential pressure acting through a virtual displacement equals the change in strain energy associated with the virtual displacement. If the virtual displacement is chosen to be $\delta w \propto \delta w_0$, then this requirement is expressed by the equation

$$\frac{\partial V}{\partial w_0}\delta w_0 = 2\pi q \delta w_0 \int_0^a \left[1-\left(\frac{r}{a}\right)^2\right]^2 r\,dr \qquad (8)$$

where q is the differential pressure on the membrane. The solution for the maximum displacement is

$$w_0 = \alpha a^3\sqrt{\frac{qa}{Eh}} \qquad (9)$$

where

$$\alpha = \sqrt[3]{\frac{6615\left(\nu^2-1\right)}{2\left(2791\nu^2 - 4250\nu - 7505\right)}} \qquad (10)$$

This work was done by Alfonso Hermida of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at*** ***www.nasatech.com*** *under the Mechanics category,* ***or circle no. 121*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
GSC-13783

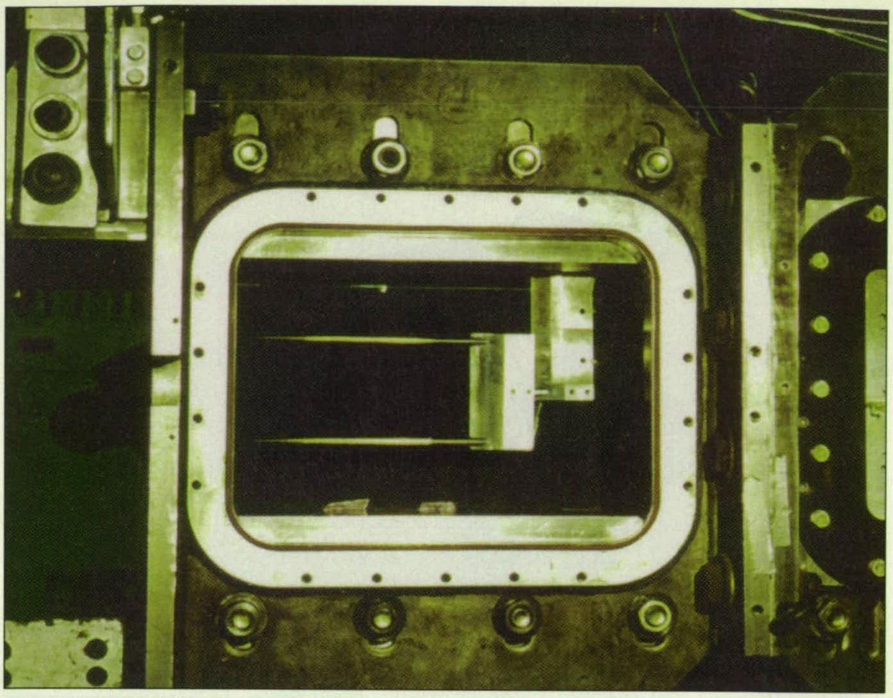
Probes for Measuring Pressures in Flowing Gases

Transient pressure is sensed in situ; steady pressure is coupled pneumatically to external sensors.

Lewis Research Center, Cleveland, Ohio

Improved pressure probes have been designed to give nearly instantaneous readings of the time-varying local static pressure in flowing gases. The probes have been installed in a wind tunnel (see figure). Probes of this type could also be particularly useful as pressure-sensing instruments to help characterize the instantaneous airflow fields about aircraft; the outputs of these and other instruments could be used, for example, as inputs to advanced digital flight-control systems. These probes could also be used to measure local time-varying pressures in natural-gas pipelines.

The probe design is modular, featuring a variety of interchangeable tips with different shapes for different flow conditions; a cone-cylinder tip is optimized for supersonic flow, whereas a sphere/cylinder tip is optimized for subsonic flow. Each probe tip contains eight radial holes that intersect an internal pneumatic passage, part of which serves as a pressure-



Two **Prototypes of the Pressure Probes** described in the text are installed in a supersonic wind tunnel.

measurement plenum. The external shape and the configuration of the passages is designed so that the pressure in the plenum equals the local static pressure of the flow field in which the flow is immersed.

A dynamic-pressure transducer located in the plenum senses the rapidly varying component of static pressure; this transducer is connected to external high-speed electronic circuitry that samples the transducer output. The probe tip is mounted on a stem, which is hollow; the stem contains both (1) wires for connection to the electronic circuitry and (2) a passage that serves as a conventional pneumatic connection between the plenum and an external transducer that measures the slowly varying component of static pressure.

In tests, prototypes of these probes were found to respond to both transient and steady pressures, as intended. In supersonic-flow tests, the probes measured free-stream static pressures correctly at mach 1.6., 2.0, and 2.5. In the worst case encountered in the tests, the root-mean-square pressure measured by the tip transducer and the time-averaged pressure measured by the pneumatically coupled external transducer differed by no more than 0.02 psi (140 Pa). Transient testing of the prototype probe configuration indicates a dynamic static-pressure-measurement capability in excess of 800 measurements per second (800 Hz).

This work was done by A. Robert Porro and Michael E. Ernst of **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 122*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16348.

Electromagnetic Smart Washer for Detecting Bolthole Cracking

New device allows engineers to detect the onset and progress of bolthole cracks without removing the bolt.

Marshall Space Flight Center, Alabama

Engineers have designed a new device, called the Smart Washer, that can electromagnetically detect bolthole cracks in metal structures. The device is a metal washer that contains a wire coil embedded onto the bottom surface of the washer. An alternating current drives this coil and induces eddy currents around the bolthole. These eddy currents develop electro-

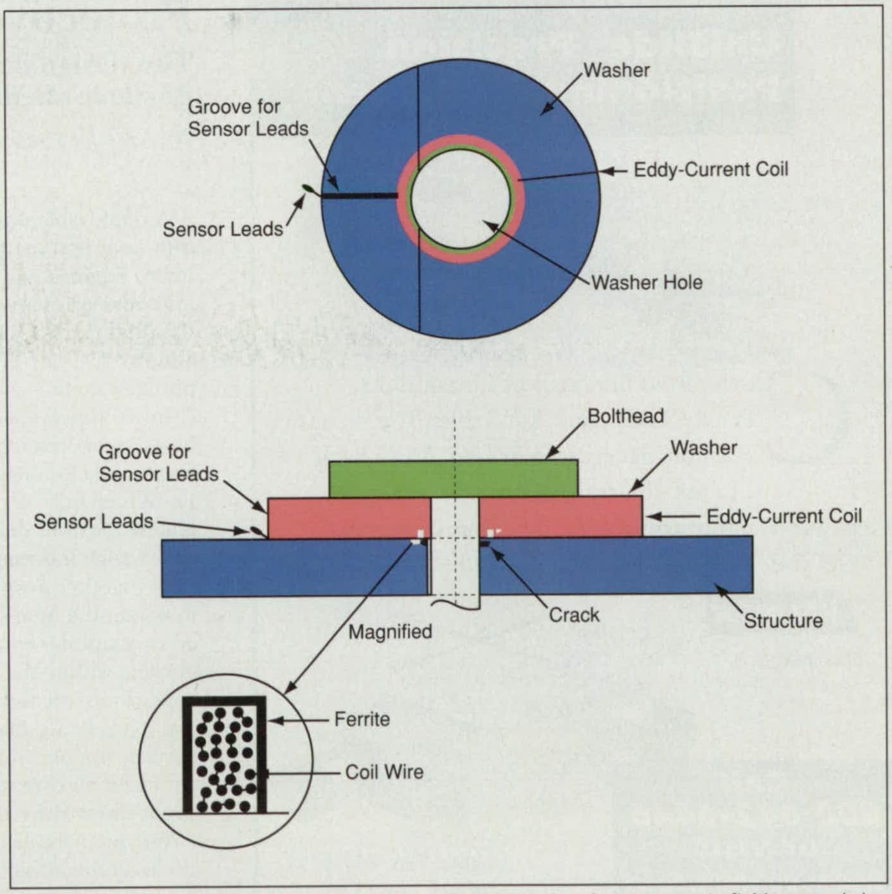
magnetic fields that interact with the driving field of the coil.

A sensor is built into the Smart Washer, enabling direct contact with the bolthole lip, which is a natural crack-formation site. The sensor is therefore ideally positioned for crack monitoring, and since the Smart Washer is a permanent part of the structure, technicians can detect bolthole cracks without removing the bolt.

Another advantage is that unlike bolts, washers are not critical structures. Since washers distribute bolt loads onto surfaces, Smart Washers can accommodate a sensor without degrading structural strength.

The Smart Washer technology has several novel features. First, unlike many sensing systems, the design allows a long cable between the local electronics of the Smart Washer and the measurement circuitry. If this cable is routed to an access port, then technicians can inspect boltholes by connecting a hand-held instrument.

Secondly, it is easy to fabricate Smart Washer sensing coils, and the measurements involve well-understood techniques that require relatively few components. The simplicity of the Smart Washer provides a robust, rugged system that can withstand field conditions.



Sensors Connected to the Smart Washer detect changes in the electromagnetic fields around the bolthole, indicating bolthole cracks.

Finally, because washers are not critical structures, designers are more willing to replace standard washers with Smart Washers, thereby adding embedded bolthole monitors to new and existing designs.

The unique capabilities of the Smart Washer have been successfully demonstrated during destructive tests. Smart Washers were mounted on 1/8-in. (3.2-mm) thick aluminum 2219-T87 coupons, where each coupon contained a 0.5-in. (13-mm) diameter drilled hole. The coupon was installed in a fatigue test machine, and the Smart Washer was fastened to the coupon with a stainless steel nut and bolt. Cyclical tensile loading induced a bolthole crack, and the Smart Washer sensor signal was recorded as the crack grew.

The Smart Washer successfully detected crack initiation and growth in conditions of dynamic loading, static loading, and unloaded conditions. In all cases, the Smart Washer could reliably detect 0.050-in. (1.27-mm) long cracks, and could track crack growth out to lengths approaching 0.200 in. (5.08 mm).

This work was done by Bruce McKee, Yuri M. Shkarlet, Atteen Khatkate, Tom Banas, Richard Ingram, and David Perkins of Innovative Dynamics, Inc., Cornell Research Park, for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 176*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
MFS-26479

Deployable and Restowable Protective Dome

The design could be adapted to tents and portable sheds.

NASA's Jet Propulsion Laboratory, Pasadena, California

A deployable and restowable dome made of flexible material with semirigid reinforcements has been developed to protect the main engines of the Cassini spacecraft against impacts by micrometeoroids during the long cruise to Saturn. The design of the dome could readily be adapted to terrestrial applications in advanced, easily erectable temporary structures like tents and portable sheds.

In its appearance and basic mechanical function, the dome bears some resemblance to covers on some vintage baby carriages and cloth rooftops on convertible automobiles (see Figure 1). When fully deployed, the dome is a hemisphere approximately 2.1 m in diameter; when fully stowed, it becomes a crescent wedge less than 15 cm thick. The flexible dome material is sewn together from gore-shaped pieces with accordionlike pleats to obtain the hemispherical shape. The dome shape is supported by graphite/epoxy semicircular hoops called stays, sewn into pockets within the material. In the original Cassini spacecraft application, the flexible material is an advanced, multilayer, thermally insulating blanket that is made electrically conductive to prevent the accumulation of static electric charge. Other, less-advanced flexible materials could likely be used in terrestrial applications like tents and sheds.

Two semicircular bows made of aluminum tubing, forming a circle on the dome at the "equator," meet at two hubs that allow them to pivot (see Figure 2). The ends of eight of the stays meet at the hub and slide in grooves, while other stays sewn into the

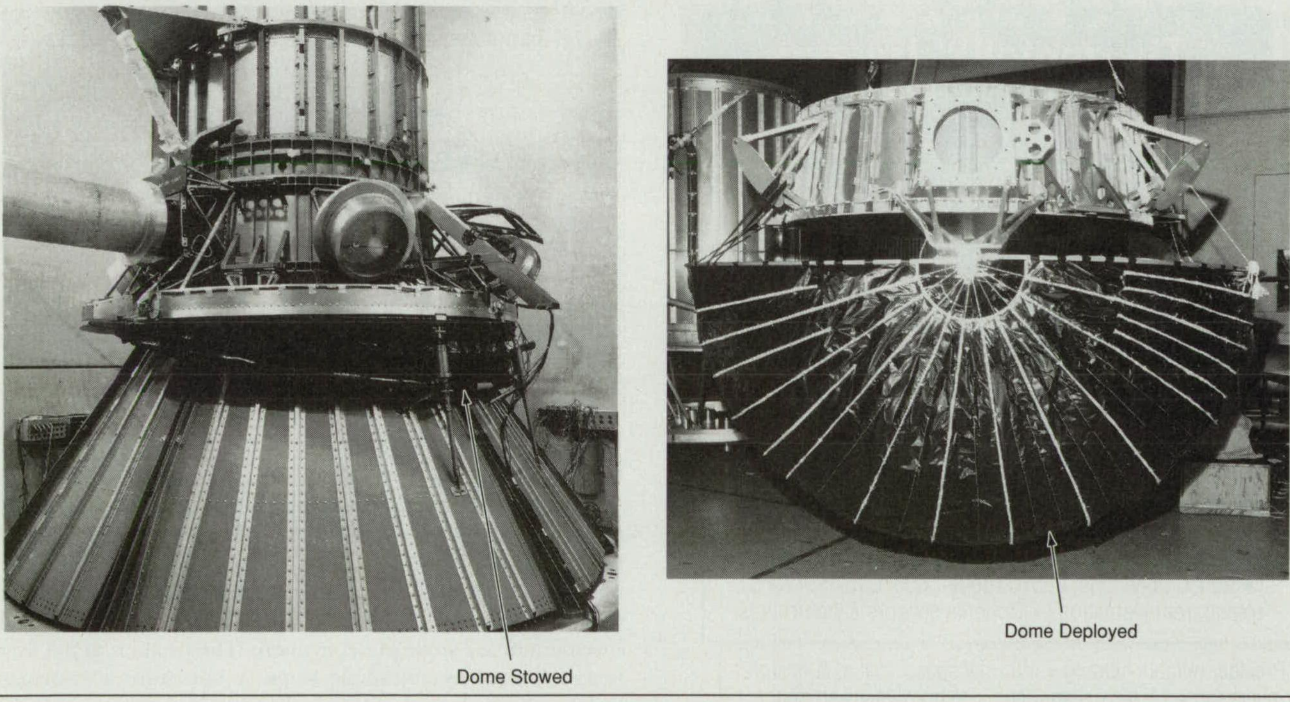


Figure 1. The **Protective Dome** can be stowed or deployed, as needed. These views show a prototype deployed in one test setup and the final product stowed for a spacecraft test.

material only support the shape of the dome. The flat shape of the stay end fittings allow the dome shape to collapse to a compact stowed position. The lollipop-shaped fittings on the ends of the stays slide freely in the slots in the hubs, with sufficient slack to allow for folding of the flexible material during stowage. One of the bows is fixed; the other is driven in rotation about the diameter to produce motion needed for deployment or stowage (see Figure 2). The drive mechanism, located at one hub, is nonback-driveable and redundant; it includes two independent, electronically commutated

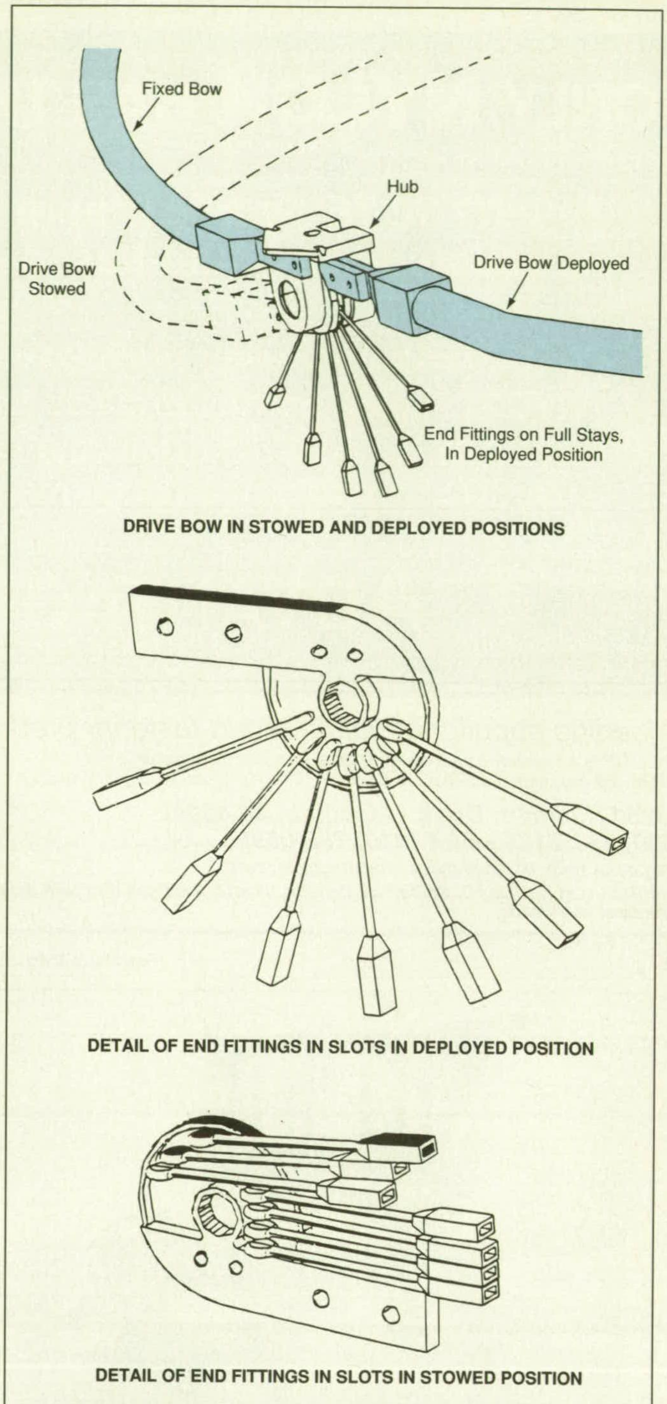


Figure 2. The **Bows and Full Stays Terminate at Hubs** at opposite ends of a diameter of the hemisphere. One of the hubs is shown here in simplified form, without the drive or idler mechanism described in the text.

dc brushless motors and two paths of 20:1 spur-gear and 605:1 harmonic output gears. In the other hub, the driven bow is retained by an idler mechanism that includes gears to transfer the rotary motion of the driven bow to a potentiometer for measurement of the angle of deployment. The rotation of the driven bow is limited by adjustable stops. A miniature lever-actuated switch at each stop provides an electrical indication that the driven bow has reached the stop.

This work was done by Donald Sevilla, Lori Shiraishi, and Randal Foehner of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 187*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge). NPO-20156*

Bidirectional Operating Actuator (BOA)

New device increases the stroke output of a piezoelectric transducer.

Marshall Space Flight Center, Alabama

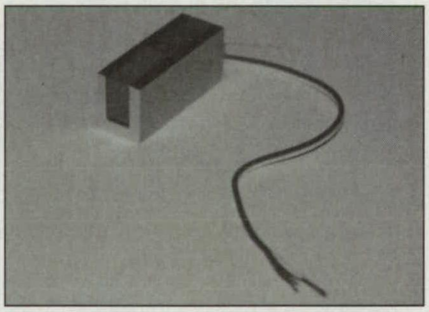
A generic actuator has been designed to amplify the piezoelectric effect. The Bidirectional Operating Actuator (BOA) amplifies the stroke of a piezoelectric element and reorients it through a kinematic linkage.

Piezoelectric transducers are typically capable of low-strain and high-force output. The strain of a piezoelectric device is less than 0.1 percent. The force output per unit area of a piezoelectric device can be as high as 40 MPa. Piezoelectric actuators are desirable because of their direct conversion of electric potential to mechanical work. Typically, piezoelectric actuators are used in situations that require high-precision micromotion.

A longer piezoelectric stroke is often needed. The stroke can be increased using a variety of methods. The most common method of piezoelectric stroke amplification is to use a bender element. In this case, a piezoelectric wafer is bonded to a substrate to form an "active" bimetallic strip. When a voltage is applied, the extension or contraction of the piezoelectric is converted to bending of the beam. Actuators used in this configuration are usually high-stroke, low-force devices.

Another method of increasing the stroke of a piezoelectric is to use a kinematic mechanism. The mechanisms can be simple lever arms or four-bar-type linkages. The most important factor in the design of a kinematic linkage is the use of flexure hinges — joints cut into a solid piece of material. The thin section of the joint is compliant in one direction, stiff in other directions.

Another significant consideration with piezoelectric transducers is the type of load on the material. Since piezoelectric is a ceramic material, it is not able to withstand large tensile or bending loads. The best way to avoid tensile loads is to apply a preload to the transducer, which allows the piezoelectric to operate in compression only. With a preload, the piezoelectric provides extension while the preload provides the return force. Preloading insures firm mechanical mating between the piezoelectric and the surrounding mechanism.



The **Bidirectional Operating Actuator** is a device for increasing the stroke output of a piezoelectric transducer.

This work was done by David V. Newton and Ephrahim Garcia of Garman Systems Incorporated, for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 152*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26425.

Electromagnetic Shaker for Flight Flutter Testing

Precise forcing functions can be applied for studying vibrational responses.

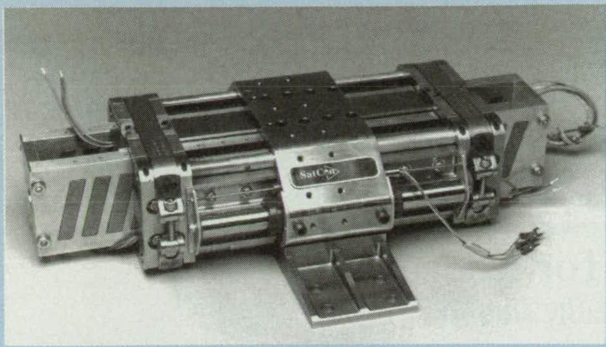
Dryden Flight Research Center, Edwards, California

An electromagnetic shaker based on a linear induction motor has been developed for use in flight flutter testing of aircraft. The shaker is a wing-tip-mounted unit capable of delivering root-mean-square forces as large as 140 lb (623 N) at frequencies from 10 to 60 Hz.

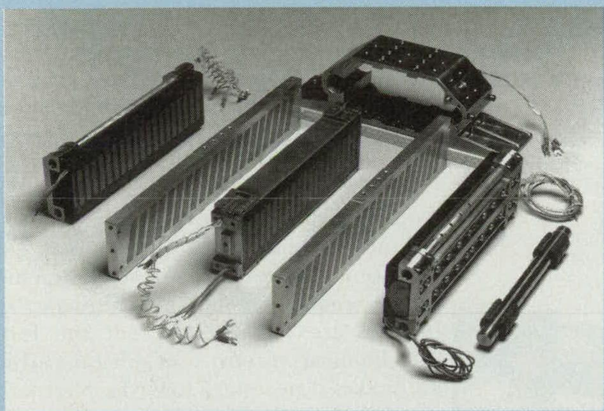
Advanced flight flutter testing methods that are undergoing development show promise for significantly improving the process of expansion of the flight envelope. However, these methods will require airborne equipment that can rapidly, repeatedly, and vigorously excite all of the critical vibrational resonances of an aircraft with precise, carefully crafted forcing functions, the time dependencies of which can be measured. These capabilities are well beyond those of previously developed shakers.

During the development of the present electromagnetic shaker, a linear induction motor (LIM) was combined with a field-oriented (vector) controller that enables the use of the LIM as a servo. The LIM can therefore be made to track an analog signal that represents the desired force as a function of time. As the LIM produces the commanded force, it accelerates and decelerates the mass of the moving portion of the LIM. The resulting reaction force on the nominally stationary portion (that is, the portion attached to a wing-tip accessory rail) is delivered to the wing. The field-oriented controller utilizes feedback from a position sensor and from phase current sensors, in order to control the force produced by the LIM.

A requirement for high force, plus tight constraints on weight and size necessitated a novel LIM design. In particular, as shown in the "disassembled" view in the figure, the LIM features two end primary windings, two secondary "ladder" conductors (each double-sided), and a middle double-sided primary winding in a multiple-airgap arrangement. The magnetic flux that emerges from an end primary winding must pass through the two secondary conductors, the middle double-sided primary winding, and the four airgaps before reaching the other end primary winding. Consequently, only the end primary windings must be provided with iron return paths, so that the shaker can be made very compact. In addition, designing the secondary conductors to be stationary and the primary windings to move enables limitation of the stationary portion of the mass of the shaker to 10.5 lb (4.8 kg).



LIM ASSEMBLED



LIM DISASSEMBLED

This **Linear Induction Motor (LIM)** is designed to satisfy a requirement for high force, plus tight constraints on weight and size.

In tests, the force that the LIM can apply was found to be limited by heating. For example, if heating were not a consideration, then the LIM could produce a force in excess of 1,000 lb (4.4 kN) at electrical breakdown while operating at a magnetic field near saturation, with ohmic losses of 10 kW. On the other hand, the LIM can produce a force of 200 lb (0.9 kN) at a more reasonable level of losses (1.0 kW) at lower fields. The foregoing results imply that at low duty cycles, one can achieve forces much greater than those achievable in continuous operation. Tests also demonstrated the ability of the shaker to follow sinusoidal force commands at frequencies up to 90 Hz.

The test results indicate the feasibility of using this and other LIM-based reaction-mass actuators for both vibration-cancellation and shaker applications. The long stroke of the LIM is particularly advantageous in that it enables the LIM to generate large forces at frequencies down to <10 Hz. It might even be possible to use actuators like the present one to replace pneumatically powered hammers in some applications.

This work was done by Fred Flynn, Ron Ghofrani, Jim Goldie, Kevin Leary, John Swenbeck, Dick Hockney, Scott Makseyn, Steve Armstrong, Gita Rao, Geoff Lansberry, Dick Satter, and Cynthia Paine of SatCon Technology Corp. under a NASA SBIR contract and Leonard Voelker of **Dryden Flight Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 156*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to DRC-98-04, volume and number of this NASA Tech Briefs *issue, and the page number.*

Manufacturing/Fabrication

Magnetron Plasma Etching of SiC for Microfabrication

Etch rates are high, and etched surfaces are remarkably smooth.

Lewis Research Center, Cleveland, Ohio

Magnetron plasma etching has been found to be a promising technique for micromachining of single-crystal silicon carbide to fabricate microscopic structures comprising integrated mechanical, electronic, and/or optical devices. Silicon carbide offers several advantages over silicon for the development of future devices: In comparison with silicon, silicon carbide is harder and stiffer, is less chemically reactive, and has greater thermal conductivity; moreover, silicon-carbide-based electronic devices can operate at temperatures higher than silicon-based electronic devices can withstand. Etching techniques for micromachining of silicon are well known, but the lesser chemical reactivity of silicon carbide makes it necessary to devise alternative etching techniques.

In research that preceded the development of the present magnetron-plasma-etching technique, it had been shown that single-crystal 6H-SiC could be etched at high rates to very smooth final surfaces in an electron-cyclotron-resonance (ECR) plasma reactor, using a mixture of CF_4 and O_2 gases. An ECR reactor provides a high-density plasma at a low pressure, which facilitates the formation and removal of volatile reaction products. However, the sample to be etched is remote from the main body of the plasma.

In the present magnetron-plasma-etching technique as in the ECR etching technique, a magnetic field is used to increase the density of the plasma. Unlike in ECR etching, the main body of the plasma is confined in proximity to the sample. Such confinement results in a high concentration of reactive chemical species together with a high flux of bombarding ions at the sample, making it possible to achieve rapid etching.

Magnetron plasma etching of SiC was demonstrated in preliminary experiments in a vacuum chamber, using a magnetron sputter gun as a cathode. For each experiment, a sample of 6H-SiC n-doped to a concentration $\approx 6 \times 10^{17}$ cm^{-3} was placed on a silicon target. The (0001) face of the sample was masked with a SiC fragment. A radio-frequency (RF) power supply was used, and the target was allowed to self-bias. CHF_3 and O_2 were fed into the chamber at rates fixed by mass-flow

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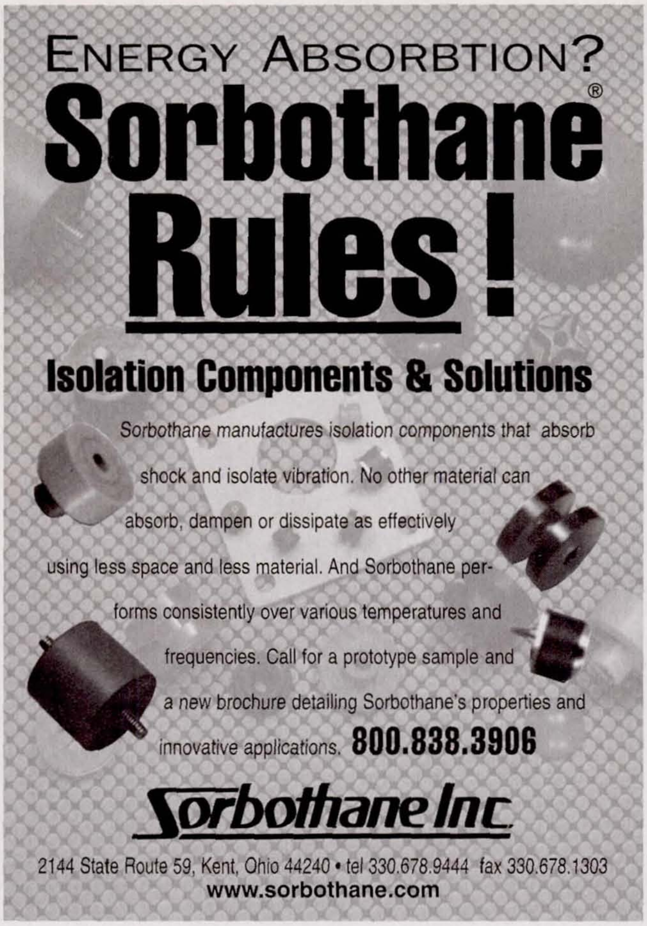

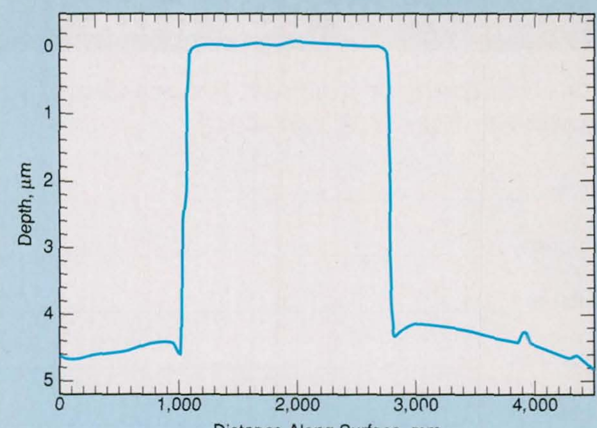

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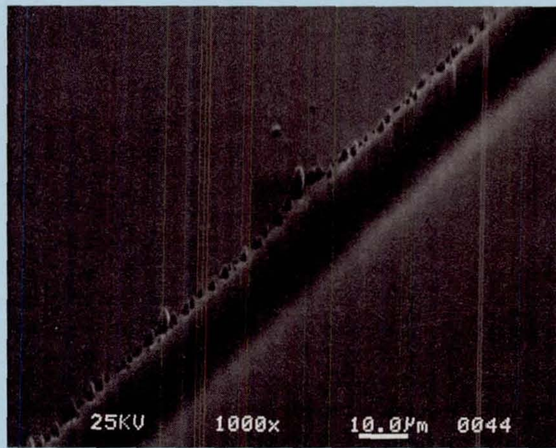

SCANNING ELECTRON MICROGRAPH

The **Profilometer Trace** was made after a 7-minute etch of 6H-SiC in 0.6 CHF_3 + 0.4 O_2 at a total pressure of 20 mtorr, at an RF power of 250 W. The scanning electron micrograph shows an edge of the etched region.

controllers. The pressure in the chamber was regulated by throttling the flow to the vacuum pump.

The duration of each etch was 7 minutes. At an RF power of 250 W, a maximum etch depth of 4.5 µm (see figure) was achieved with a gas mixture of 0.6 CHF_3 + 0.4 O_2 at a total pressure of 20 mtorr (about 2.7 Pa). This depth corresponds to an etch rate of about 640 nm per minute, which is a relatively high rate, significantly higher than that which has been achieved using an ECR plasma. The etched surface was found to have a root-mean-square surface roughness of only 20 Å. The reaction of aluminum and fluorine yields a nonvolatile product, which makes aluminum suitable for use as a mask material in order to provide selective etching in fluorine-based plasmas. At the RF power of 250 W, aluminum films were etched at a high rate. At an RF power of 50 W, silicon carbide was etched at a rate of 170 nm per minute, while aluminum was etched at 1/12 of that rate.

This work was done by Glenn Beheim of **Lewis Research Center** *and Carl Salupo of Cortez III Service Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category,* ***or circle no. 188*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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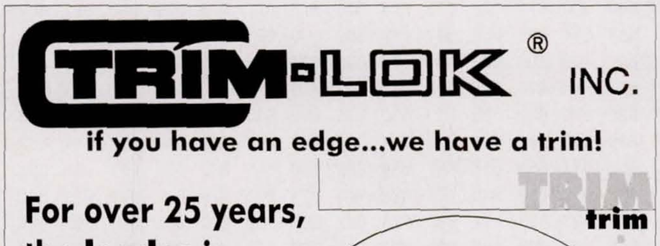

Books & Reports

Control System for Steerable, Rooftop-Mounted Antenna

An excerpt from JPL Document D-12104 presents additional information on the control system of a steerable microwave antenna that is mounted on the roof of a land vehicle and used to communicate with a geostationary satellite. The antenna and control system were described previously in "Steerable K/Ka-band Antenna for Land-Mobile Satellite Applications" *NASA Tech Briefs,* Vol. 18, No. 1 (January 1994), page 28. Under control by a computer mounted in the vehicle, a motor turns a rotary table to aim the antenna in azimuth toward the satellite, which transmits a pilot-tone signal that serves as an aiming beacon. (The radiation pattern of the antenna is wide enough in elevation so that steering in elevation is unnecessary.) Once the pilot tone has been acquired, an inertial turn-rate sensor mounted in the vehicle provides most of the information needed by an open-loop control subsystem that keeps the antenna pointed toward the satellite as the vehicle moves. Drift of the inertial-sensor bias is the source of most aiming error. Any such error is detected by sinusoidally dithering the rotary table by $\pm 1^\circ$ at a frequency of 2 Hz while measuring the resulting dither in the strength of the received pilot tone.

This work was done by Arthur C. Densmore of Caltech and Richard Renner of Cal Corporation for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the excerpt, "Subsystem Design," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 189*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19863

Evaluation of Additives to PFPEs in Boundary Lubrication

A report describes experiments on the wear-reducing performances of six additives to perfluoropolyether (PFPE)-based fluids in the boundary-lubrication regime. The additives were a phosphate, a thiophosphate, a β-diketone, a benzothiazole, an amide/thiol, and a sulfite. Each additive was dissolved, at a concentration of 1 weight percent, in a PFPE based on hexafluoropropene oxide. The resulting formulation was exposed to the boundary-lubrication regime in a four-ball vacuum tribometer at a temperature ≈23 °C, an initial Hertzian stress of 3.5 GPa, and a sliding speed of 28.8 m/s. The wear rate for each formulation was determined from the slope of wear volume as a function of sliding distance.

This work was done by William R. Jones, Jr., of **Lewis Research Center***; Bradley A. Shogrin of Case Western Reserve University; Pilar Herrera-Fierro of Ohio Aerospace Institute; and Tzuhn-Yuan Lin and Hajimu Kawa of Exfluor Research Corp. To obtain a*

copy of the report, "Evaluation of Boundary-Enhancement Additives for Perfluoropolyethers," access the Technical Support Package (TSP) ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 165*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Overview of Tapered-Slot Antennas

A document presents a comprehensive overview of the technology of tapered-slot antennas and arrays of such antennas. The fundamental operation of tapered-slot antennas is not yet fully understood, and, for lack of established design rules, the designs of these antennas have been based primarily on empirical results. The document combines results of previous research and development with more-recent design information and measurement data to provide a better understanding of the fundamental operation of tapered-slot antennas and arrays. The better understanding provided by the document is intended to contribute to the establishment of design guidelines.

This work was done by Richard Q. Lee of **Lewis Research Center** *and Rainee N. Simons of NYMA, Inc. To obtain a copy of the document, "Tapered Slot Antenna," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 198*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16570.

Micromachined Monopropellant Thrusters

A report proposes monopropellant microthrusters for a new generation of miniature spacecraft with mission lifetimes stretching into years. These thrusters would include micromachined nozzle/chamber assemblies containing microvalves, designed according to emerging concepts of microelectromechanical systems (MEMS). Like some previously designed monopropellant thrusters, these thrusters would generate expanding gases and thereby generate thrust through catalytic dissociation of liquid hydrazine; however, these thrusters would be considerably smaller. Moreover, instead of putting catalytic pellets in chambers according to the previous designs, one would roughen the inner walls of the chambers and coat them with iridium or some other suitable catalyst. The micromachined thruster assemblies would be enclosed within aerogel bodies for thermal insulation. Each thruster would be heated with a small amount of power (< 1 W) to promote vaporization. Flow geometries and the characteristic times of residence and dissociation of hydrazine would be optimized.

This work was done by Philip Moynihan and Carl Guernsey of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Monopropellant Hydrazine Microthruster," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category,* ***or circle no. 180*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20159

NASA Test Facility Upgrades Computers

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NASA's White Sands Test Facility has two concrete blockhouses like this one, and four support bunkers to control the test firings.

NASA's White Sands Testing Facility (WSTF) near Las Cruces, NM, is a leading center of real-time computing for testing space propulsion systems with up to 60,000 pounds of thrust. In order to keep pace with increasingly sophisticated and critical engine designs, NASA needed to upgrade the firing and data acquisition systems. For the space shuttle, minimum firing impulse was 80 milliseconds; then came smaller engines that fire in 20 milliseconds; and the Propulsion Test Office required controls that operated four times as fast.

The RISC system, running under REAL/IX (MODCOMP's implementation of UNIX System V), was installed to control firing. The system has a single 50-MHz, 32-bit MC88110 RISC microprocessor; 64 MB of dynamic RAM; and is rated at 150 MIPS. Digital Equipment Corp. Alpha Server 1000 systems gather data from the test firings. There are 660 analog-to-digital conversion channels that include 20 high-speed channels; together they can collect one million samples per second.

The new control systems are based on open systems technology that utilizes the UNIX operating system and can use readily available parts and software modules. Near-real-time data is available to on- and off-site customers for display, reduction, and analysis. NASA maintains up to 100 GB of past test data online for reference by engineers and propulsion system developers.

According to Ron Lerdal, NASA's computer operations manager for the White Sands Propulsion Test Office, the facility deals with expensive, hazardous, one-of-a-kind test articles, like the orbiting maneuvering system. Firing commands must be issued precisely because the Orbital Maneuvering System has a hypergolic engine — it operates simply by mixing a fuel and an oxidizer. It will operate properly only in the vacuum of space. If the valves that allow fuel and oxidizer to mix aren't operated precisely, the engine could explode. "You don't want a command issued at the wrong time," said Lerdal. "We need a computer that will do the same thing, at the same time, every time you operate it — not a computer that gets around to doing what you want when it wants."

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NASA Wind Tunnel Gets Power Boost

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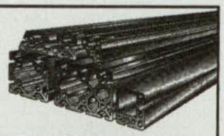

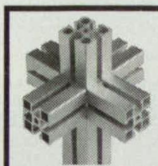

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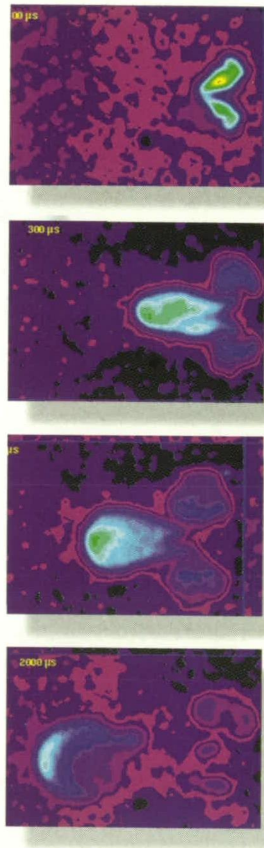
False color images generated by Planar Laser Induced Fluorescence (PLIF) imaging represent the relative concentration of hydroxyl radicals in the expanding flame.

Image courtesy of The Aerospace Corporation.



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Thousands of other people also use IDL to turn their data into useful information. People like Dr. Amir Najmi, of Johns Hopkins University Applied Physics Lab, who is developing optimal processing methods for electromagnetic and acoustic data. "Once I have an idea," says Najmi, "I can quickly prototype that idea and see the results almost instantly."

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